Species Status Assessment Report
for the
American Burying Beetle
(*Nicrophorus americanus*)


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Version 1.0

February 2019

Species Status Assessment Report for the American Burying Beetle *Nicrophorus americanus*

Prepared by the
U.S. Fish and Wildlife Service
February 2019

EXECUTIVE SUMMARY

This Species Status Assessment (SSA) report is a summary of information assembled and reviewed by the U.S. Fish and Wildlife Service (Service) and incorporates the best scientific and commercial data available. The SSA framework (U.S. Fish and Wildlife Service 2015, entire) is intended to support an in-depth review of the species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. SSAs are not a decision document; rather, the report provides information that helps inform various types of decisions.

To evaluate the biological status of the ABB, both currently and into the future, we assessed a range of potential scenarios to allow us to consider the species' resiliency within populations and the viability of the species over its range. Several factors influence the resiliency of a population to stochastic events. Important factors are habitat availability, carrion availability and climate conditions. As we consider the future viability of the species, higher overall species viability is associated with more populations with high resiliency distributed across the range of the species.

The ABB is the largest silphid (carrion beetle) in North America, and is native to 35 states in the United States and the southern borders of three eastern Canadian provinces, covering most of temperate eastern North America. The species is believed to be extirpated from all but nine states in the U.S. and likely from Canada. Based on the last 15 years of records, the ABB is now known to occur in portions of Arkansas, Kansas, Oklahoma, Nebraska, South Dakota, and Texas (not documented since 2008), on Block Island off the coast of Rhode Island, and reintroduced populations on Nantucket Island off the coast of Massachusetts and in southwest Missouri. Reintroduction efforts are also underway in Ohio, but survival of reintroduced ABBs into the next year (successful over-wintering) has not yet been documented. A potential report of an ABB in Michigan in 2017 is being investigated to determine if the area supports ABBs.

We have assessed the ABB's levels of resiliency, redundancy, and representation currently and into the future by ranking the condition of each population. We generally refer to ABB populations as clustered, localized areas, roughly defined by habitat differences or other geographical features, with inter-breeding ABB individuals. However, there are no clear boundaries separating many of the areas known to be occupied by ABB. So for the purposes of this analysis we've organized the current range of the ABB into analysis areas that follow broad geographic and ecological patterns (Figure ES-1). The Southern Plains analysis areas include the Red River, Arkansas River, and Flint Hills analysis areas. The Northern Plains analysis areas include the Loess Canyons, Sandhills, and Niobrara River analysis areas and the New England Analysis Area includes Block Island off the coast of Rhode Island, and a reintroduced population on Nantucket Island off the coast of Massachusetts. This is the scale of "populations" referred to in the analysis of risk factors potentially affecting the species (Chapters 4 and 5).

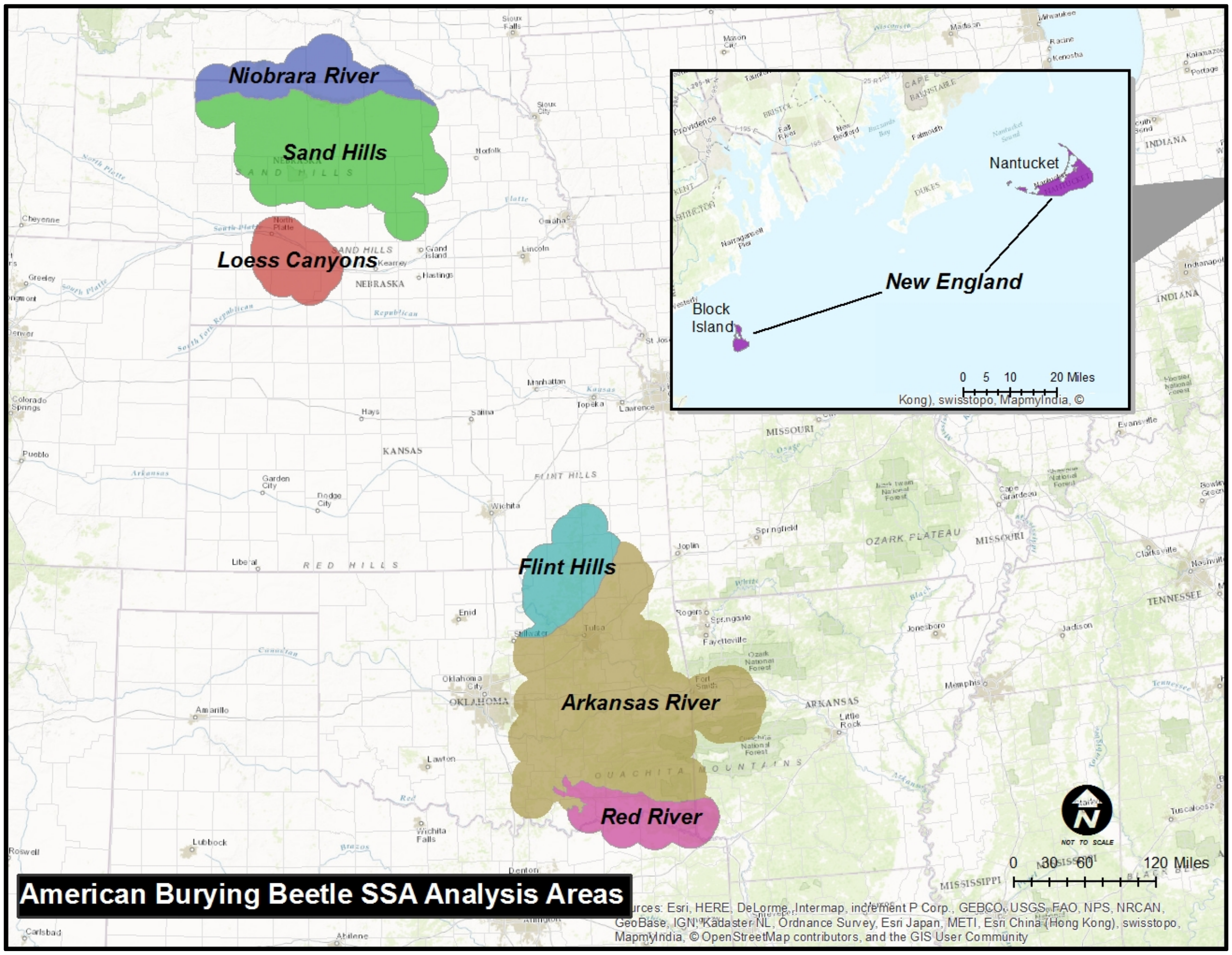

Figure ES-1. American Burying Beetle Species Status Assessment seven analysis areas.

This SSA is a qualitative assessment of the relative condition of the seven analysis areas based on the knowledge and expertise of species experts, as well as all available published and unpublished information. Our analysis of the past, current, and future influences on ABB long term viability revealed that there are two known factors that pose the largest risk to the future viability of the species. These risks factors are primarily habitat impacts due to land use and effects related to climate change. Other important factors (such as the availability of appropriate sized carrion for reproduction, or soil moisture) are all dependent on, or affected by, the habitat loss or alteration related to land use and climate.

We have forecasted ABB resiliency, redundancy, and representation under two future plausible land use change scenarios and under two different climate change emission scenarios through 2099. Land use scenarios were evaluated separately and then combined with climate scenarios. The scenarios included the following assumptions about stressors to the populations:

Land Use Change Scenarios

Scenario 1: Continued Current Rate of Land Change and High Management/Protection

- Urban expansion rate of 10% for northern and southern plains analysis areas and 20% for the New England Analysis Area.
- A 5% increase in conversion from grassland/pasture to cropland for Northern Plains analysis areas.
- A 2% increase in conversion from grassland/pasture to cropland for Southern Plains analysis areas.
- Management of all existing protected lands is assumed to continue. Some limited areas of protected lands may be added or expanded.
- A potential 30% reduction in conditional habitat in the Southern Plains analysis areas to reflect temporary agricultural impacts like high utilization of vegetation via grazing or mowing for hay.

Scenario 1 Results (without climate changes) – Agricultural land uses and urban expansion are predicted to have some impacts to ABB habitat and populations over time, but the impacts affect a relatively small percentage of the analysis areas. Relative to current conditions, there are no changes anticipated in condition categories for future habitat, population factors, resiliency or viability under scenario 1 for land use changes alone (Table 5-9). Resilient populations would potentially be present through 2099 in all analysis areas except the Red River Analysis Area. The existing trend for the Red River Analysis Area has been a relatively rapid decline in the last ten years with only 9 positive surveys in the last 10 years and only 7 positive surveys in the last five years. The redundancy provided by the Red River Analysis Area currently appears to be very limited and could be discounted for the future. ABBs are likely to be extirpated from the Red River Analysis Area in future years, but the population decline does not appear to be due to land use changes.

Scenario 2 : Accelerated Rate of Land Change, Low Management

- Urban expansion rate of 20% for Northern and Southern Plains analysis areas and 30% for the New England Analysis Area.
- A 30% increase in conversion from grassland/pasture to cropland for Northern Plains analysis areas.
- A 5% increase in conversion from grassland/pasture to cropland for Southern Plains analysis areas.

- No specific management for ABBs and no new protected lands.
- A potential 60% reduction in conditional habitat in the southern plains analysis areas to reflect temporary agricultural impacts like high utilization of vegetation via grazing or mowing for hay.

Scenario 2 Results (without climate changes) – Agricultural land uses and urban expansion are predicted to have impacts to ABB habitat and populations over time, but the impacts affect a relatively small percentage of the analysis areas. There are minor changes anticipated in condition categories for future habitat, population factors, resiliency or viability under scenario 2 for land use changes alone (Table 5-9). Resilient populations would potentially be present through 2099 in all analysis areas except the Red River, Loess Canyons and New England analysis areas. The resiliency of the New England Analysis Area is considered low under scenario 2 without active management.

Future Climate Scenarios

The projections of climate change in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (documents issued in 2013 and 2014) were based on four scenarios developed by teams of scientists a few years earlier. These scenarios, known as Representative Concentration Pathways (RCP) scenarios 2.6, 4.5, 6.0, and 8.5, were designed to span the range of values in the scientific literature, from low to intermediate to high, for "radiative forcing" (RF) as of 2100 and the different pathways by which various RF conditions might be reached. RF relates to atmospheric conditions which are the result in part, but not entirely, of emissions of greenhouse gases; with increasing RF, global temperature rises and other changes in climate occur. The RCPs are widely used throughout the scientific community for modeling a broad range of possible future climate conditions.

In our analysis of potential climate change impacts to the ABB, we utilized two of those scenarios, RCP 4.5 and 8.5, over different blocks of time through the end of this century. RCP 4.5 is at the low end of the intermediate range of conditions and represents a situation under which key atmospheric conditions would stabilize at a relatively moderate level shortly after 2100, RCP 8.5 is the high end of such conditions. For ease of reference we refer to these as "Emissions Scenarios" although they are not based solely on emissions of greenhouse gases. Our approach of using the two RCPs is consistent with the current widespread scientific practice of considering projections based on RCP 4.5 and RCP 8.5 so as to consider a range of projected conditions, rather than relying on a single scenario. The US Global Change Research Program is using these two RCPs as the core scenarios for the ongoing development of the Fourth National Climate Assessment, and they also are used as the basis for projections generated via the US Geological Survey's National Climate Change Viewer. We did not use RCP 2.6, due to numerous scientific papers showing that although it is theoretically possible to achieve this pathway and outcome, key assumptions underlying it already have not been met (including a very rapid reduction in GHG emissions) and other future activities it relies upon are highly speculative.

Moderate Emissions Scenario (RCP 4.5) –Under conditions projected using this moderate RCP scenario , the Southern Plains Analysis Areas has a increased risk of being extirpated by 2040-2069 (Table ES-1), leaving only the Northern Plains and New England populations. Resiliency of the remaining New England populations could be low without adequate management for the ABB. The Loess Canyons Analysis Area is also projected to have low resiliency due to red cedar expansion and sensitivity to droughts. With this significant loss of resiliency in four of the seven analysis areas, plausible reductions in resiliency in the Northern Plans populations and known limitations of the New England populations, representation and redundancy would be impacted, affecting overall viability of the species.

High Emissions Scenario (RCP 8.5) – At the high emissions level, ABB populations in Southern Plains analysis areas very likely would be extirpated by 2040-2069 (TableES-1) and populations in the Northern Plains analysis areas could be extirpated by 2070-2099. Temperatures and other climate conditions in the Northern Plains analysis areas are projected to approach or meet thresholds that do not support ABB populations near the end of the 2040-2069 time period. The New England Analysis Area could maintain moderate resiliency through 2099 with active management, but with population loss in 6 analysis areas, redundancy and representation would be greatly reduced. Viability for the species would be considered very low.

Table ES-1. Future resiliency under two (RCP 4.5 and 8.5 climate emission scenarios.

	Future Resiliency - Including Future Climate						
Analysis Area	Future Resiliency with Land Use (from Table 5-4)	Climate Change (2010 - 2039)		Climate Change 2040 - 2069)		Climate Change (2070 – 2099)	
		Moderate Emissions RCP 4.5	High Emissions RCP 8.5	Moderate Emissions RCP 4.5	High Emissions RCP 8.5	Moderate Emissions RCP 4.5	High Emissions RCP 8.5
Northern Plains							
Niobrara River	Moderate	Moderate	Moderate	Moderate	Moderate-Low	Moderate-Low	Ø
Sand Hills	High	High	High	High	High	High	Ø
Loess Canyons	Low	Low	Low	Low	Low	Low	Ø
Southern Plains							
Flint Hills	Moderate	Low	Low	Ø	Ø	Ø	Ø
Arkansas River	High	Low	Low	Ø	Ø	Ø	Ø
Red River	Low	Ø	Ø	Ø	Ø	Ø	Ø
New England							
Block& Nantucket	Moderate-Low	Moderate-Low	Moderate-Low	Moderate-Low	Moderate-Low	Moderate-Low	Moderate-Low

3Rs	Parameters	Current Condition	Future Condition (Viability out to 2099 with projected land use and climate change scenarios)
Resiliency: Population (Large populations able to withstand stochastic events)	Primary indicators of resiliency are geographic distribution of ABBs within analysis areas and relative abundance and available habitat with each analysis. Area	• 6 analysis areas with moderate to high resiliency • 1 analysis area with low resiliency and 2 reintroduced populations • Extirpated from about 90% of the historic range	• Land use changes alone have relatively minor effects except for the New England Analysis Area • 3 southern populations are extirpated with moderate (RCP 4.5) climate projections • All but the New England populations are extirpated with high (RCP 8.5) climate projections. Northern Plains populations could be extirpated by about 2070.
Representation (genetic and ecological diversity to maintain adaptive potential)	Genetic information and geographic distribution of populations is being used to describe representation for the ABB.	• Overall representation is considered moderate. • The current known range does include populations from northern, southern, eastern and western areas of the ABB range, but representation from eastern areas is limited to small New England island populations.	• With moderate (RCP 4.5) climate projections, representation would be reduced with the loss of genetic and ecological diversity represented by the southern populations • With high (RCP 8.5) climate projections, nearly all representation would be lost and only the New England populations may remain
Redundancy (Number and distribution of populations to withstand catastrophic events)	The number and geographic distribution of ABB populations (measured with existing survey data)	• Current redundancy could range as high as 9 “populations” (including reintroduced populations) • 6 populations, if we only count populations that are considered self-sustaining.	• With moderate (RCP 4.5) climate projections, 3 Northern Plains and 1-2 New England populations maintained • With high (RCP 8.5) climate projections, only 1-2 small populations in New England (moderate/low resiliency) maintained

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CHAPTER 1: INTRODUCTION

The American burying beetle, (ABB) *Nicrophorus americanus,* occurs in various habitat types in portions of nine states: Arkansas, Kansas, Massachusetts, Missouri (recently reintroduced, experimental population), Nebraska, Oklahoma, Rhode Island, Texas (not documented since 2008), and South Dakota Based on the last 15 years of records. Reintroduction efforts are also underway in Ohio, but survival of reintroduced ABBs into the next year (successful over-wintering) has not yet been documented. A report of an ABB in Michigan in 2017 is being investigated to determine if the area supports ABBs populations. Surveys in 2018 failed to verify the report, but additional surveys are planned in 2019 (Figure 1-1). The ABB was designated as an endangered species in 1989 (54 FR 29652) and a recovery plan was prepared in 1991 (USFWS 1991).

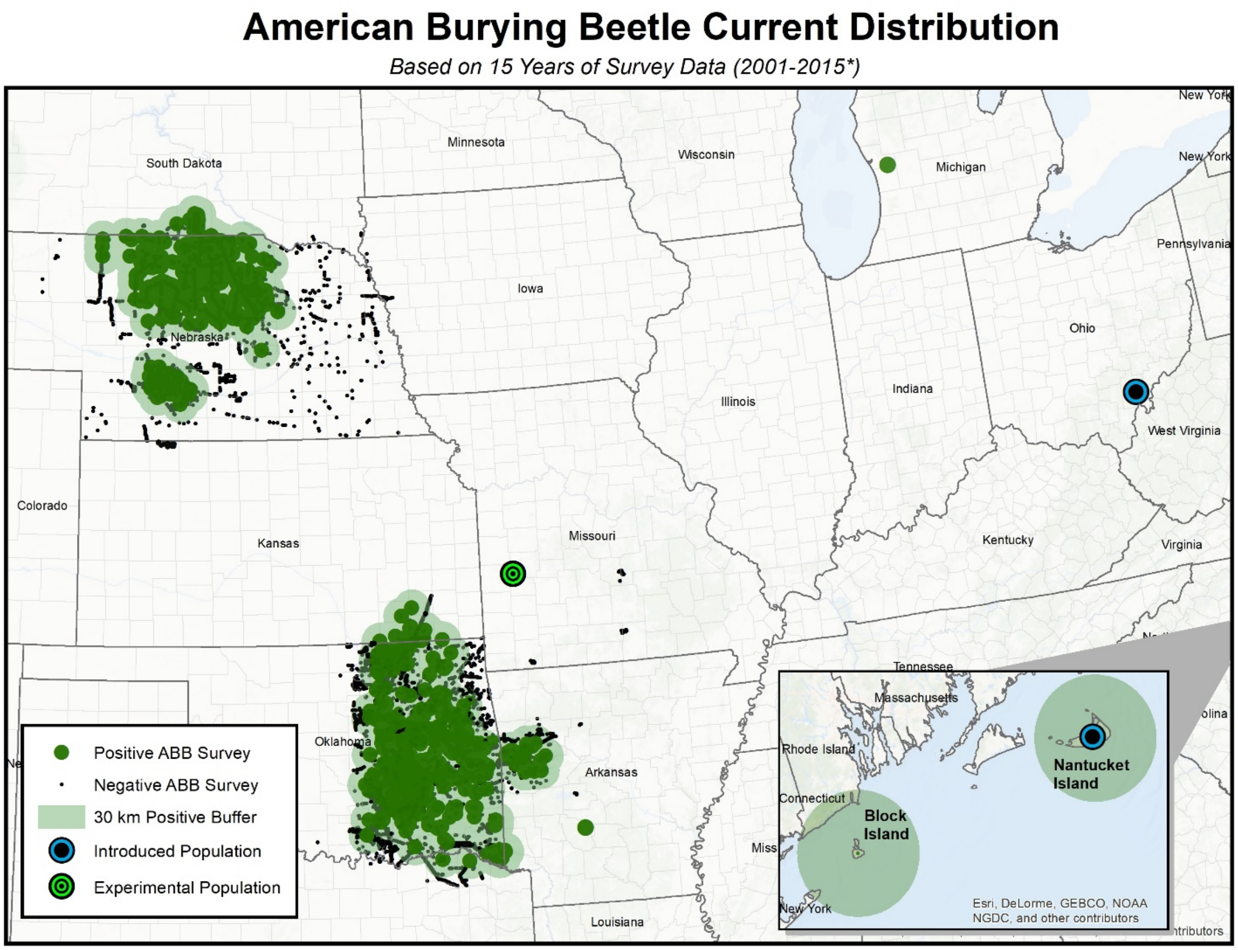


Figure 1-1. Current known distribution of the American burying beetle (*survey data based on 2001-2015 except for 2017 Michigan occurrence).

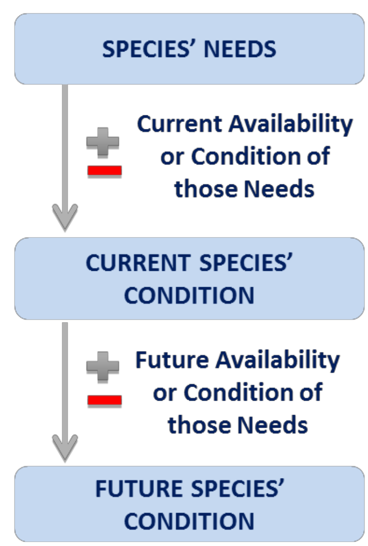
This Species Status Assessment (SSA) report is a summary of information assembled and reviewed by the U.S. Fish and Wildlife Service (Service) and incorporates the best scientific and commercial data available. The SSA framework (U.S. Fish and Wildlife Service 2015, entire) is intended to support an in-depth review of the species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. This SSA report documents the results of the comprehensive status review for the ABB.

The Service is engaged in a number of efforts to improve the implementation of the Endangered Species Act (ESA) (see www.fws.gov/endangered/improving_ESA). As part of this effort, our Endangered Species Program has developed the SSA framework to guide how we assess the biological status of species. Because biological status assessments are frequently used in all of our Endangered Species Program areas, developing a single, scientifically sound document is more efficient than compiling separate documents for use in our listing, recovery, consultation, and other conservation programs. Therefore, we have developed this SSA Report to summarize the most relevant information regarding life history, biology, and considerations of current and future risk factors facing the ABB. In addition, we forecast the possible response of the species to various future risk factors and environmental conditions to provide a complete risk analysis for the ABB.

The objective of the SSA is to thoroughly describe the viability of the ABB based on the best scientific and commercial information available. Through this description, we will determine what the species' needs, its current condition in terms of those needs, and its forecasted future condition. In conducting this analysis, we take into consideration changes that are likely happening in the environment – past, current, and future – to help us understand what factors drive the viability of the species.

For the purpose of this assessment, we define viability[1] as a description of the ability of a species to sustain populations in the wild beyond a biologically meaningful time frame. Using the SSA framework, we consider what the species needs to maintain viability by characterizing the status of the species in terms of its resiliency, representation, and redundancy.

Species Status Assessment Framework



> **Resiliency** describes the ability of a species to withstand either periodic or stochastic disturbance events, not rising to the level of catastrophic. Resiliency is positively related to population size and growth rate and may be influenced by connectivity among populations. Generally speaking, populations need abundant individuals within habitat patches of adequate area and quality to maintain survival and reproduction in spite of disturbance. We can measure resiliency based on metrics of population size and condition; in the case of the ABB, the primary indicators of resiliency are geographic distribution of ABBs within analysis areas and

[1] Viability is not a specific state, but rather a continuous measure of the likelihood that the species will sustain populations over time. USFWS 2015. Draft Species Status Assessment Framework. Version 3.3 October 2015., p. 8.

relative abundance (both measured by analysis of survey data) and available habitat with each analysis area.

Representation describes the ability of a species to adapt to changing environmental conditions. Representation can be measured through the breadth of genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the species' range. The more representation or diversity the species has, the higher its potential of adapting to changes (natural or human caused) in its environment. Geographic distribution of occupied and potentially suitable habitat and genetic information is being used to describe representation for the ABB.

Redundancy describes the ability of a species to withstand catastrophic events. A catastrophic event is defined here as a rare destructive event or episode affecting many populations and occurring suddenly. Redundancy is about spreading the risk and can be measured through the duplication and broad distribution of resilient populations across the range of the species. The more resilient populations the species has, distributed over a larger area, the better chances that the species can withstand catastrophic events. For the ABB, we are using the size and geographic distribution of populations (measured with existing survey data) and of occupied and potentially suitable habitat (measured with geospatial analyses) to describe redundancy.

To evaluate the viability of the ABB both currently and into the future, we assessed a range of conditions to allow us to consider the species' resiliency, representation and redundancy.

The format for this SSA Report includes the following chapters:

1. Introduction;
2. Species Biology and Needs. The resource needs of individuals and a framework for what the species needs across its range for species viability;
3. Risk Factors. The likely causes of the current and future status of the species, and determining which of these risk factors affect the species' viability and to what degree;
4. Current Conditions. The species' current range, habitat conditions, and population estimates; and
5. Future Conditions and Viability. A description of the viability in terms of resiliency, representation, and redundancy.

Additional supplemental information and analysis was used to complete this SSA Report. We prepared a geospatial analysis using Geographic Information Systems (GIS), and the corresponding GIS Analysis Report is presented in Appendix A. Supporting climate analyses is found in Appendix B and literature cited in this SSA Report is found in Appendix C.

Importantly, this SSA Report does not result in, nor predetermine, any decisions by the Service under the ESA. In the case of the ABB, the SSA does not determine whether the ABB continues to warrant protections of the ESA, or whether it should be proposed for downlisting or delisting under the ESA. That decision will be made by the Service after reviewing this document, along with the supporting analysis, any other relevant scientific information, and all applicable laws, regulations, and policies. The results of a decision will be announced in the *Federal Register*. Instead, this SSA Report provides a strictly scientific review of the available information related to the biological status of the ABB.

CHAPTER 2: SPECIES BIOLOGY AND NEEDS

2.1 SPECIES TAXONOMY

The American burying beetle (ABB) *Nicrophorus americanus* is a member of the beetle family Silphidae (subfamily Nicrophorinae); these beetles are known by their habit of burying vertebrate carcasses for reproductive purposes and for exhibiting parental care of young. The genus *Nicrophorus* contains about 70 species world-wide, of which 15 occur in North America (Peck and Kaulbars 1987, entire). Globally, burying beetles are restricted to temperate climates, and high elevations in tropical climates (Arnett 1946; Howden & Peck 1972; Cornaby 1974; Young 1978; Howden & Peck 1985; Peck & Anderson 1985; Trumbo 1990; Smith *et al.* 2000; Ruddiman 2001; Sikes & Venables 2013). Both population densities and species diversity of *Nicrophorus* are higher in northern localities where habitat generalists and habitat specialists occur in sympatry (Scott 1997 et al., entire). Reasons for burying beetles' lack of success in southern locales include increased competition with ants, flies, and perhaps vertebrates, as well as increased temperatures and rates of carcass decomposition (Anderson 1982, entire; Trumbo 1990, p. 6-7; Scott et al. 1997, entire). *Nicrophorus americanus* is probably most closely related to the similarly sized, *Nicrophorus germanicus* of the Old World. In its extant populations, the geographic distribution of *Nicrophorus americanus* overlaps with *N. carolinus, N. marginatus, N. pustulatus*, *N. tomentosus*, and *N. orbicollis*, from which it differs physically in coloration and size. Within North American *Nicrophorus, Nicrophorus americanus* is most similar to *N. orbicollis. Nicrophorus americanus* was first described by Olivier in 1790 (Entomologie, II, Paris), with the type locality undesignated.

2.2 SPECIES DESCRIPTION

The ABB is the largest silphid (carrion beetle) in North America, reaching 1.0 to 1.8 inches (25-35 cm) in length (Anderson 1982, p. 362; Backlund and Marrone 1997, p. 53). The beetles are black with orange-red markings (Figure 2-1). Their hardened elytra (wing coverings) are smooth, shiny black, and each elytron has two scallop shaped orange-red markings. The pronotum over the mid-section between the head and wings is circular in shape with flattened margins and a raised central portion (Ratcliff 1996, pp. 54, 62). The most diagnostic feature of the ABB is the large orange-red marking on the raised portion of the pronotum, a feature shared with no other members of the genus in North America (USFWS 1991, pp. 2-4). The ABB also has an orange-red frons (the upper, anterior part of the head), and a single orange-red marking on the clypeus, which can be viewed/considered as the lower "face" located just above the mandibles. Antennae are large, with notable orange club-shaped tips for chemoreception.

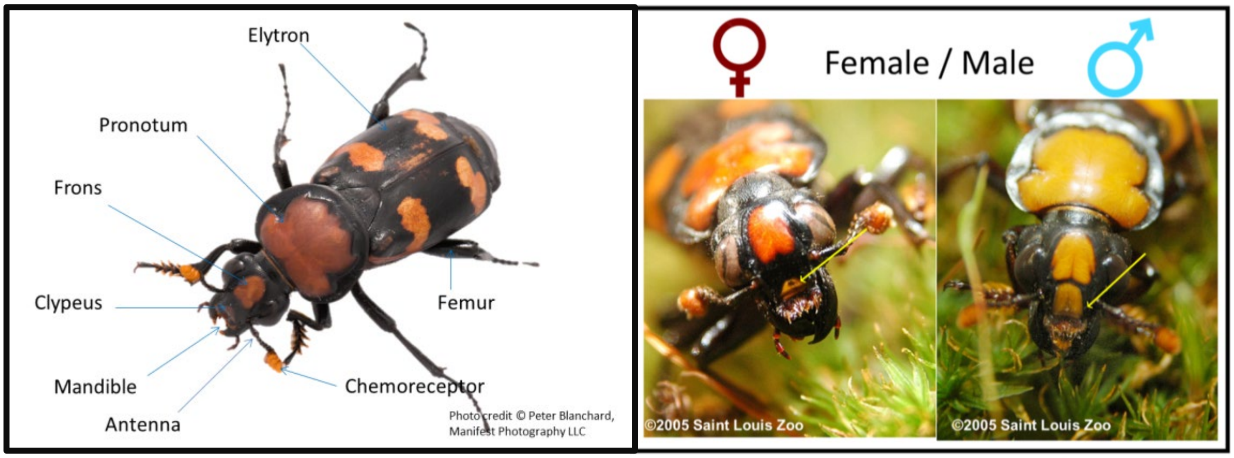


Figure 2-1. American burying beetle anatomy.

Gender can be determined from markings on the clypeus: males have a large, rectangular, red marking and females have a smaller, triangular, red marking. The ABB is an annual species that may live up to 12-16 months. Age of ABB's can be categorized as teneral, mature, or senescent. Age of adults is determined by intensity of color (younger individuals appear to have more vibrant color) and the overall condition of the body and appendages. Marking of a teneral beetle are brighter with the elytron and pronotum macula appearing more uniform in color, the exoskeleton is softer and more translucent looking, and the elytron pubescence is more pronounced. On a second year adult, (one that has overwintered) the pronotum appears more orange than the elytra. Senescent beetles are more scarred, often with pieces missing from the margin of the pronotum or elytra, have cracks in the exoskeleton, and/or appendages are missing (e.g., tarsi legs, antennae (Bedick et al. 1999, p. 175.)

2.3 RANGE

Historically, the known geographic range of the ABB included 35 states in the United States and the southern borders of three eastern Canadian provinces, covering most of temperate eastern North America (Figure 2-2; Anderson and Peck 1985, p 54; USFWS 1991, p. 5; Peck and Kaulbars 1987, p. 75). Historical records document ABBs occurrence from the east coast to Nebraska in the 1920s. However, documentation of records is not uniform throughout this broad historical range. More records exist from the Midwest into Canada and in the northeastern United States than from the southern Atlantic and Gulf of Mexico region and some portions of southeastern United States have few or no records (USFWS 1991, p. 6). During the 20th century, the ABB disappeared from over 90 percent of its historical range (Lomolino et al. 1995, p. 606). The last ABB specimens along the mainland of the Atlantic seaboard, from New England to Florida, were collected in the 1940s (USFWS 1991, pp.6-8). At the time of ESA listing in 1989, known populations were limited to one on Block Island, Rhode Island; and one in Latimer

County, Oklahoma. After the species was listed, survey efforts increased and the ABB was discovered in more locations, particularly in South Dakota, Nebraska and Oklahoma. The ABB is now known to occur in portions of Arkansas, Kansas, Oklahoma, Nebraska, South Dakota, and Texas (not documented since 2008), on Block Island off the coast of Rhode Island, and reintroduced populations on Nantucket Island off the coast of Massachusetts and in southwest Missouri. Reintroduction efforts are also underway in Ohio, but survival of reintroduced ABBs into the next year (successful over-wintering) has not yet been documented.

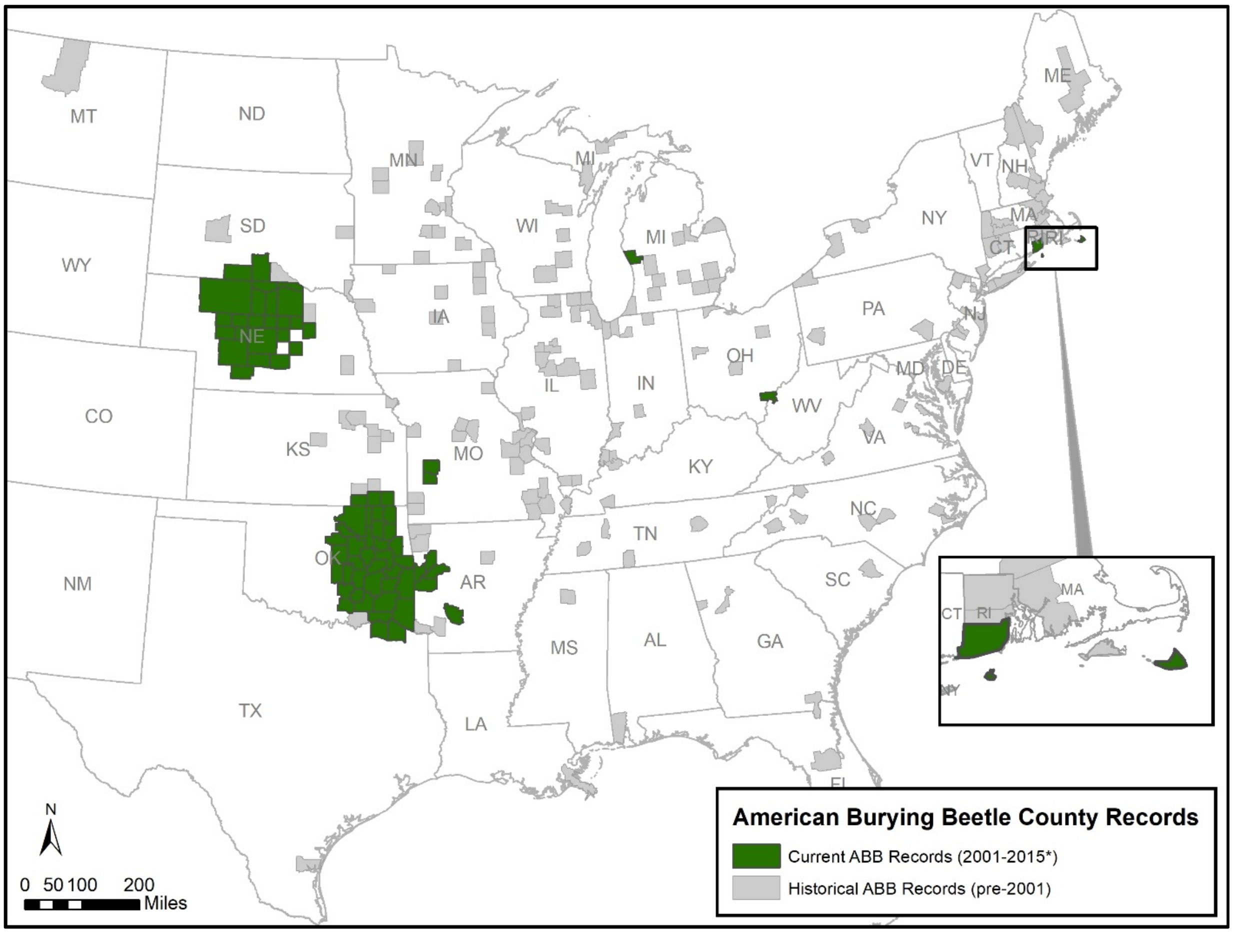


Figure 2-2. Current and historic range of the American burying beetle, by county/province (*survey data based on 2001-2015 except for 2017 Michigan occurrence).

A potential report of an ABB in Michigan in 2017 is being investigated to determine if the area supports ABBs. Michigan surveys in 2018 failed to confirm the report of ABBs, but additional surveys are planned in 2019. We do not have enough information on the Michigan report to confirm or assess the status of ABBs in this area.

2.4 LIFE HISTORY AND INDIVIDUAL NEEDS

The life history of the ABB is similar to that of other burying beetles (Pukowski 1933, entire; Scott and Traniello 1987, p 693; Kozol et al. 1988, p 173; Wilson and Fudge, 1984, entire). The ABB is a nocturnal species that lives for only about one year. American burying beetles are active from late spring through early fall, occupying a variety of habitats and bury themselves in the soil to hibernate for the duration of the winter. Reproduction occurs in the spring-early summer. New adult beetles or offspring (called tenerals), usually emerge in summer, over-winter (hibernate) as adults, and comprise the breeding population the following summer (Kozol 1988, p 2; Amaral et al. 2005, pp. 30, 35). Adults and larvae depend on dead animals (carrion) for food, moisture, and reproduction. Figure 2-3 below provides an overview of the ABB's life history and individual needs, which is discussed in more detail in the following sections.

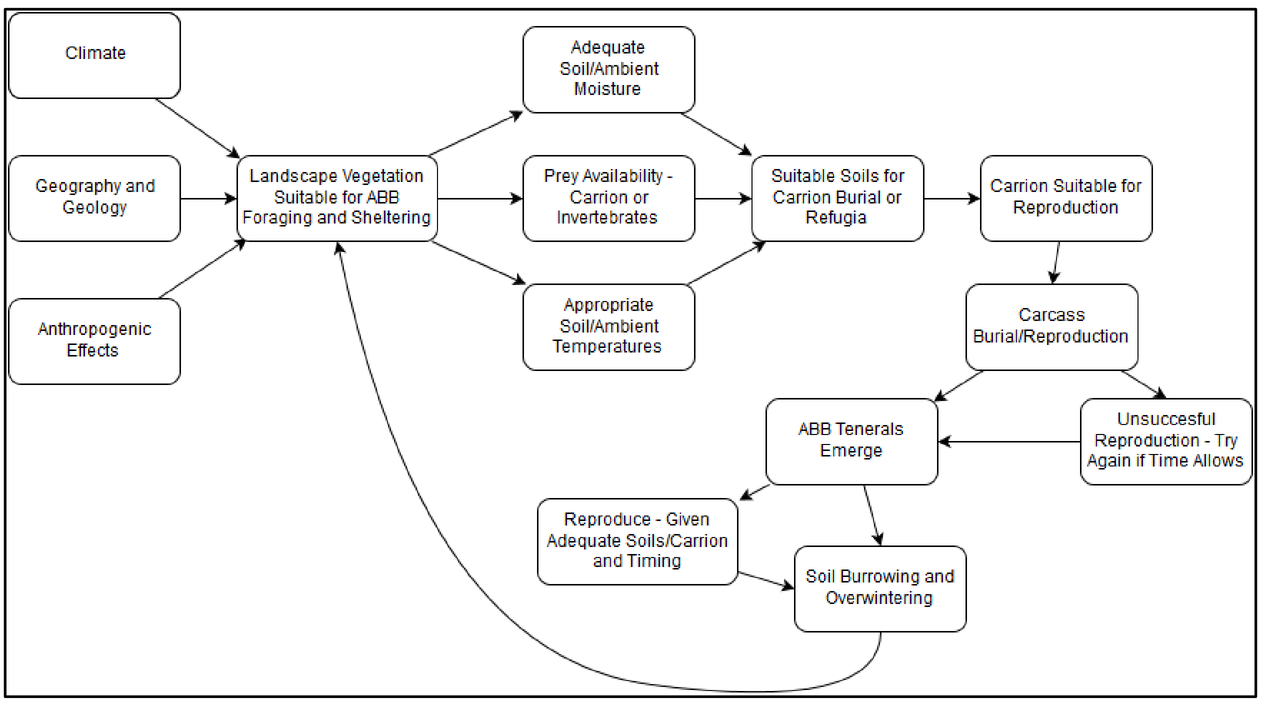


Figure 2-3. American burying beetle ecology diagram.

2.4.1 Active and Inactive Periods

Inactive Period: When the nighttime ambient air temperature is consistently below 59°F (15.0°C), ABBs bury into the soil and become inactive (USFWS 1991, p. 11; Scott and Traniello 1989, p. 34–35; Kozol 1995, p. 11). This inactive period typically extends from late September through mid-May (Figure 2-4) in the southern portions of the range, (Arkansas, Kansas and Oklahoma) (Kozol 1990c, p. 4; USFWS 1991, p. 11; USFWS 2008, p 13). In the northern portion of their range (New England, Nebraska and South Dakota), the inactive period usually extends from early September through May or early June. The length of the inactive period can fluctuate depending on air temperature, and in cooler, more northern latitudes this period is typically longer. Studies in Nebraska have found that overwintering *N. orbicollis* move throughout the soil column during the winter to stay at or just below the frost line to avoid freezing. Researchers also found a strong relationship between depth and soil temperature, with depth increasing as temperatures decrease (Conley 2014; pp.35–68). Surface vegetation structure (i.e., woodland vs. grassland) does not appear to influence over-winter survival rates (Holloway and Schnell 1997, pp.148–151).

Data suggest that over-wintering results in significant mortality (Bedick *et al*. 1999, p. 13), ranging from 25 percent to about 70 percent, depending on year, location, and availability of carrion in the fall (Schnell et al. 2008, entire; USFWS 2008b, p. 13). Schnell et al. (2008, p. 483) found that ABBs that were provided a carcass had a higher survival rate in an over-wintering study, but ABBs do not attempt to bury carcasses in the fall (when it is unknown if ABBs select areas near a carcass to over-winter, but are still attracted to carcasses to forage and may select areas under or near carcasses to over-winter. Antidotal evidence indicates that ABBs overwinter with carrion at least on occasion. At a site in eastern Oklahoma, American burying beetles were observed in association with carcasses placed in the field in early October, well after the breeding season. Specifically, several beetles were found in small tunnels dug into the soil directly under rat carcasses (J. C. Creighton, pers. comm. 2016). In fact, a number of the beetles in our experiment constructed the same type of tunnels into the soil under provided carcasses (Schnell et al. 2008, entire). Experimental results indicate that one can enhance overwinter survival by provisioning American burying beetles with carrion (Schnell et al. 2008, entire).

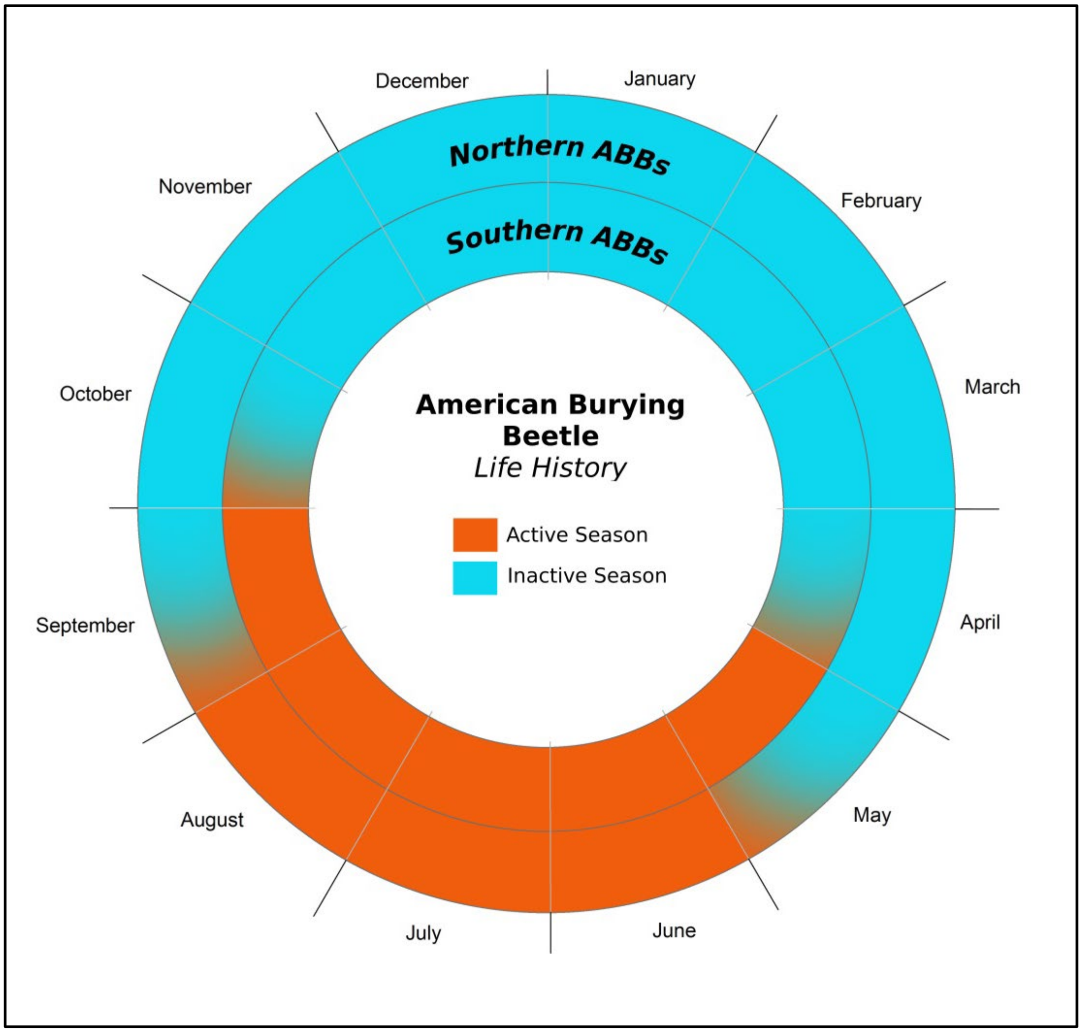


Figure 2-4. American burying beetle active and inactive periods for northern and southern populations.

Active Period: ABBs emerge from their winter inactive period when ambient nighttime air temperatures consistently exceed 59º F (15 °C) (Kozol 1988, p. 11; Kozol 1990c, p. 4; Bedick et al 1999 p. 179; USFWS 2008 p. 13). Typically, ABBs are active from May through September in southern portions of its range, but in more northern latitudes of their range, the active period is typically June through August (Figure 2-4). The ABBs are active at night and during their active period; they are most active from two to four hours after sunset. No captures have been recorded immediately after dawn (Walker and Hoback 2007, p. 304; Bedick et al. 1999, entire). During the daytime, ABBs are believed to bury under vegetation litter or into soil (Jurzenski 2012, p. 76.) ABBs begin reproductive activity and rearing their young (broods) soon after emergence from overwintering (Figure 2-5). During May and June ABBs secure a mate and carcass for reproduction and reproductive process takes approximately 50-60 days (Kozol 1988, p. 41).

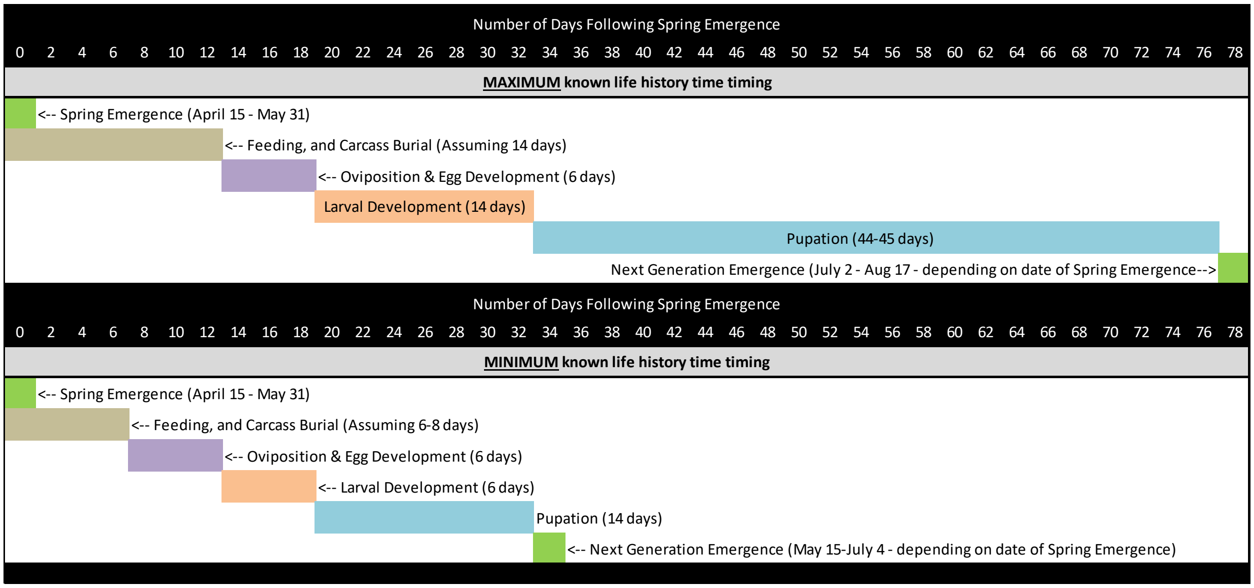


Figure 2-5. American burying beetle reproductive timing, representing differing ranges of timing from American burying beetle and surrogate species literature.

Weather conditions, such as rain and strong winds, can result in reduced ABB activity (Bedick et al. 1999, pp.178-180). However, on Block Island, Rhode Island, burying beetles were successfully trapped repeatedly on both rainy and windy nights, provided the temperature was above 59º F (15º C, Kozol et al. 1988, p. 11).

Trapping capture rates for ABBs can be used to estimate population densities and activity levels. Capture rates are highest from mid-June to early-July and again in mid-August (Kozol et al. 1988, pp.36-37; Bedick et al. 2004, pp. 66-67; USFWS 1991, p 11) across the more northern latitudes within the range of the species, however survey data shows captures per unit effort in Oklahoma is highest in July (unpublished Service data), indicating a possible phenological difference between the north and south populations.

2.4.2 Movement

Individual ABBs must fly to find food, a mate, and an appropriate sized carcass on or near suitable soils for burial. This could require individual ABBs to move considerable distances to fulfill these needs. American burying beetles are nocturnal and have been reported moving distances up to 18 miles (mi) (29 kilometers (km)) in a single night in Nebraska, in the direction of the prevailing wind (Jurzenski 2012, p. 36; Jurzenski et al. 2011, p. 135; Bedick *et al* 2004, pp.66-67). While Raithel et al. (2006, entire) previously found that wind direction plays a role when ABB are traveling long distances; wind direction showed no affect for short distance moves, and longer distance moves tended to be downwind. Bedick et al. (2004, p. 66) reported five recaptures from distances of 2-4 mi (3–6 km). However, Bedick et al. (1999, p. 176) found that of the 158 ABBs recaptured, 85% moved 0.3 mi (0.5 km) or less per night. Creighton and Schnell (1998, p. 284) reported ABB movements between sites averaged 0.74 mi (1.23 km) nightly in their search for carrion (n=23 movements between sites) with a range from 0.16 mi (0.25km) for 1 night to a maximum of 6.2 mi (10.0 km) over 6 nights.

A limitation related to movement information from most mark and recapture studies, is that marked individuals are released during the day and near the trap they were captured in. ABBs are nocturnal and typically will not move far from a daylight release site until nightfall. When they become active that night, they could be attracted to the bait in the nearby trap and recaptured at the same location, or another nearby trap. Existing information from mark and recapture studies (discussed above) suggests that most nightly movements are relatively short (less than 0.5 miles, or 0.8 km), but these estimates may not accurately reflect natural ABB movement patterns due to limitations in monitoring the potential longer movement distances of individuals. There are indications that ABB individuals have potential to move long distances over an active season if resources they need cannot be found in an area (Jurzenski 2012, Chapter 1, p. 1-23).

2.4.3 Feeding and Hydration

When not involved with brood rearing, carrion selection by adult carrion beetles for food can include an array of available carrion species and sizes, as well as feeding through capturing and consuming live insects (USFWS 1991, p. 11) and eating fly larvae when encountered on a carcass (Trumbo 1994, p. 247). The ABB has been shown to be attracted to an array of vertebrate carcasses including mammals, birds, (Kozol et al. 1988, p. 170) and herptiles (Bedick 1997, p. 32) and Kozol et al. (1988, p. 170) found no preference for avian verses mammalian carcasses. Baited traps could be attracting ABBs for both feeding and potential reproduction, but reproduction includes feeding because ABB adults and larvae feed on carcasses that are buried for reproduction. ABBs did not bury carcasses past mid-August, near the end of the assumed reproductive season, but were attracted to carcasses for feeding (Kozol 1988, pp. 36-37; Kozol 1990A, p. 6; Creighton pers. comm. 2016). ABBs do not bury carcasses for feeding only and can use carcasses of all sizes as food.

Nicrophorus carrion beetles get moisture from soils or the food they eat, and will readily drink with access to water but desiccate rapidly without some amount of moisture (Bedick *et al*. 2006, entire). *Nicrophorus* beetles have high water loss rates and likely seek moist microhabitats to avoid desiccation (Bedick et al. 2006, entire). Bedick et al. (2006, entire) looked at a congener of ABB and found that during the summer months, there can be high mortality of burying beetle (Coleoptera: Silphidae) species in pitfall traps containing dry soil, if left unserviced for more than 12 hours. Burying beetles possess a “combination of behavioral and morphological characteristics” that could render them particularly susceptible to desiccation (Bedick et al. 2006, entire). For example, the ABB’s truncated elytra and a proclivity to secrete defensive fluids appear to be unusual features for animals living without access to water or in hot, arid environments (Bedick et al. 2006, p. 24). *Nicrophorus* mortality in traps is drastically reduced if high humidity conditions exist or if access to water is provided (Bedick et al. 2006, entire).

Laboratory and field measures reveal that ABBS seek moist soils. Hoback 2008, (pp. 2, 4) allowed ABBs within an enclosure to select between moist loam, dry loam, wet sand and dry sand soils, with and without leaf litter. The average soil moistures were 11 % for the wet sand and 1.5 % for the dry sand. Soil moisture was an average of 30% for wet loam and 5% for dry loam. Approximately 70% of tested ABBs selected moist loam soil with the vast majority also being found associated with leaf litter. Approximately 20% of tested beetles were found in wet sand with the majority being found not associated with leaf litter.

2.4.4 ABB Habitat

2.4.4.1 Suitable Vegetation

The ABB is considered a generalist in terms of the vegetation types where it is found, as it has been successfully live-trapped in a wide range of habitats, including wet meadows, partially forested loess canyons, oak-hickory forests, shrub land and grasslands, lightly grazed pasture, riparian zones, coniferous forest, and deciduous forests with open understory (Walker 1957, entire; USFWS 1991, pp.14-17, 2008, pp.8-11; Creighton et al. 1993, entire; Kozol 1995, p. 8; Lomolino et al. 1995, entire; Lomolino & Creighton 1996, entire; Jurzenski 2012, pp.47-72; Willemssens 2015, pp.5-6). Individuals do not appear to be limited by vegetation types as long as food, shelter, and moisture are available and have been recorded moving between and among these habitat types (Holloway and Schnell 1997, entire; Creighton and Schnell 1998, entire).

Holloway and Schnell (1997, entire) found at Fort Chaffee, Arkansas that trapping success of *N. americanus* was higher at sites where small mammals are more abundant, irrespective of habitat defined on the basis of general vegetative characteristics. ABBs occurrence in an areas is widely believed to depend on the presence of small mammals, birds and other sources of carrion necessary for completion their life cycle (Anderson 1982, entire; Muths 1991, p. 450; USFWS 1991 p. 11; Amaral et al. 1997 p. 131; Bishop et al. 2002, entire).

American burying beetles are rarely found in areas such as agricultural lands that are tilled frequently. In the Nebraska Sandhills ecoregion, the probability of ABB presence may decrease near agricultural areas where over 73% of the habitat is cropland (Jurzenski et al. 2014 p. 10). They are not found in areas that are permanently inundated with water, although they may use wetland areas that are only seasonally flooded or seek moist soils near areas with water. Habitats that are frequently altered by mowing or other land uses where vegetation height is typically 8 inches or less are unsuitable in southern portions of the ABB range. Urban areas with manicured lawns or where access to top soil is unavailable (pavement), etc. are also considered unsuitable habitat.

2.4.4.2 Importance of Moisture

ABBs require appropriate soils to bury themselves for shelter and require adequate levels of soil moisture to avoid desiccation. ABBs seek moist areas and burrow into these areas during inactive periods (Bedick et al. 2004, p. 28). Hoback (2008, p. 1) reported that during periods of daily inactivity ABBs sought out moist soils or were under leaf litter, but it is not currently known if there are specific preferences for each *Nicrophorus* species (Jurzenski 2012, p. 76). Approximately 70% of beetles tested were found in moist loam soil with the vast majority also being found associated with leaf litter. Approximately 20% of tested beetles were found in wet sand with the majority being found not associated with leaf litter. Individual survival is also influenced by air and soil temperature, moisture, or combined temperature and moisture (Kozol 1988, entire; Scott 1998a, entire; Bedick et al. 2006, entire; Willemssens 2015, entire). This can be demonstrated by the distribution of ABB across its current known range, especially at the western and southern edges, which appear to be precipitation or climate related. The observed deaths of ABB associated with pitfall trapping in arid environments suggesting that relative humidity and soil moisture are most likely limiting factors in the distributions of *Nicrophorus* species, including ABB. Since the Service began requiring the addition of moisture to baited pitfall traps, ABB mortality has been reduced from almost 20% to practically 0, demonstrating that a proper moisture component is a required resource need for ABB survival (USFWS unpublished ABB trapping data.)

2.4.4.3 Habitat Associations

ABBs are successful across several habitat types and exhibit high niche overlap with most other species of burying beetles. The wide variety of suitable habitat types and large historic range demonstrates ABB's generalist nature; although their selection of suitable carrion for reproduction may be much more narrow (Lomolino and Creighton 1996, p. 240). While many congeners coexist with ABB, their niches usually vary, parsing out individual needs among species. The ABB's range also appears to be limited by temperatures to the south and precipitation/moisture to the west in ways that may limit habitat associations.

ABB habitat associations can vary due to local conditions and assumptions about habitat suitability that apply in one area may not apply in another. For example, two models were developed for two different habitat areas in Nebraska. In the Nebraska Sandhills model, loamy sand soil, wetlands, and precipitation variables were positively associated with ABB presence. Loam soil, crop lands, woodlands, developed lands and maximum air temperature were found to have a negative relationship with ABB presence (Jurzenski et al. 2014, p. 7). ABB occurrence also was modelled using similar methods for the Loess Canyons region of Nebraska (McPherron et al. 2012, entire). The 2011 Loess Canyons model found woodlands to have a positive influence on ABB occurrence and wetlands to have a negative influence. The modelled outcomes for these two different ecoregions identified different variables and different positive or negative associations to predict ABB occurrence. The ABB needs to avoid desiccation, which is more likely to occur in dry upland areas with quick-draining sand. Wetland areas in the Sandhills generally are wet due to elevated ground water levels and retain water and have more soil moisture in areas with sandy soils (Jurzenski et al. 2014, p. 8). These examples in Nebraska elucidate the local differences of ABB habitat associations and that extrapolation beyond specific ecoregions should be done with caution. A variable that was in agreement with both models was the negative influence of agriculture (Jurzenski et al. 2014, p. 10). The negative relationship found between agriculture development and ABB presence in both models supports the idea that within Nebraska ABBs are restricted to their current range because of habitat destruction and modification (Sikes and Raithel 2002, entire). The same thought applies to the Sandhills' model selection of developed areas as a negative predictor (Jurzenski et al. 2014, p. 10).

2.4.4.4 Foraging Habitat

Foraging habitat for the ABB is generally not assumed to be limiting, provided carrion resources are available. The ABB will forage on a wide variety of carrion and other invertebrates in a variety of habitats. Carrion for foraging is less limiting than carrion for reproduction because it does not need to be buried or prepared. Large carrion, such as a dead raccoon or deer, are too large to be buried, but can attract large numbers of foraging carrion beetles. Some habitats and vegetation types tend to support higher densities of potential carrion, but preferred habitat for foraging could vary by location. Relatively little research has been focused on ABB foraging, but it is logical that the density and types of carrion can influence the quality of foraging habitat. For example larger carrion are easier to detect and will last longer than small carrion for foraging ABBs. Large carrion that provides a food source for a longer period of time may be more important in the fall when ABBs may not be flying as much (due to cooler night time air temperatures), but ABBs may still be active in the soil beneath the carcass (depending on soil temperatures).

2.5 POPULATION AND RANGEWIDE NEEDS

2.5.1 Overview of Species Needs

The ABB needs properly functioning ecosystems that contain suitable soils sufficient to support diverse vegetative communities that sustain appropriate wildlife populations such that suitable carrion to facilitate reproduction is available. Suitable soils must contain the appropriate abiotic elements (soil temp, soil moisture, particle size, etc.) that are favorable for excavation and formation of brood chambers and contribute to proper growth and development of young. Soils that are too compact prevent ABBs from completing their reproductive cycle or if compaction occurs after the onset of reproduction, may affect ABB young emerging during the following spring. Additionally soils that are unsuitable may prohibit ABBs from overwintering underground during periods of adverse weather conditions. If the ABB cannot bury themselves during these periods, considerable localized mortality may occur.

These suitable areas must be of sufficient size to support the survival of adequate numbers of individual ABBs such that the opportunity to find a mate is not diminished and that the presence and abundance of carrion to support breeding and feeding are uninterrupted. The ABB is an annual species and is dependent upon annual reproduction to sustain extant populations. Sufficiently sized areas also contribute to opportunities for populations to at least remain stable over time. Ideally areas should be of sufficient size to support a positive growth rate and enable populations to expand over time. Smaller populations typically are more susceptible to random demographic and environmental events that negatively influence persistence over time. These suitable areas also must be connected with other suitable, occupied ABB habitats so that gene flow and genetic diversity are maintained, if not enhanced, and individuals have access to refugia, when needed, across the landscape.

The Service does not currently have information on the minimum size of suitable areas (habitat patch size) needed to maintain a viable population of ABBs. The minimum area to support a viable population would be dependent on the habitat quality which could include climate, soils, vegetation, carrion availability, predators, and competition.

2.5.2 Reproduction

Reproductive activity for the ABB usually begins in May to June once ambient nocturnal air temperatures in the general area approach 59°F (15.5°C) consistently and ABBs cease burying carcasses by mid-August (Kozol 1988, pp. 36-37; Kozol 1990a, p. 6; Creighton pers. comm. 2016). Immediately upon emergence from their winter hibernation, ABBs begin searching for a mate and proper sized carcass for reproduction. Burying beetles are capable of finding a carcass between one and 48 hours following death of prey and at a distance of at least two mi (3.2 km), but finding them after 24 hours is more typical (Conley 1982, entire). Success in finding carrion depends upon many factors including availability of optimal habitats for small vertebrates (Lomolino and Creighton 1996, entire), density of competing invertebrate and vertebrate scavengers, individual searching ability, reproductive condition (Wilson and Knollenberg 1984, p. 165) and nighttime air temperature (Wilson et al. 1984, p. 211; Ratcliffe 1996, pp.60-65; Wilson and Fudge 1984, pp.197-198). The ABB has been shown to be attracted to an array of vertebrate carcasses including mammals, birds, (Kozol et al. 1988, p. 170) and herptiles (Bedick 1997, p. 32) and Kozol et al. (1988, p. 170) found no preference for avian verses mammalian carcasses. Consequently, it is widely believed that ABB will use any carcass for reproduction, as long as it is within the favored weight class to maximize fecundity, but further investigation is required to determine the actual resource ABB uses *in situ*.

While the ABB has life history requirements similar to other carrion beetles, it is the largest *Nicrophorus* in North America and requires a larger carcass to reach its maximum reproductive potential (i.e., to raise a maximum number of offspring) than the other burying beetles (USFWS 1991, p. 2; Kozol et al. 1988, p 37; Trumbo 1992, pp. 294-295). Potential carrion sources for reproduction are carcasses weighing from 1.7-10.5 ounces (48 – 297 g), with an optimum weight of 3.5-7.0 ounces (80-200 g) (Kozol 1988, pp. 12-13, 25, 36-39, figures 1-2, Kozol 1990a, pp. 7-8).

During the active season, ABBs must fly to find a mate and appropriate-sized carcass on or near appropriate soils for burial, and compete with other ABBs (intraspecific competition) and congeners (interspecific competition) for those carcasses. Competitive advantages for congeners can be based on season, time of day, temperature, habitat, or size of carrion. An example is in northern areas of the U.S. where *N. orbicollis* is larger and can displace *N. defodiens* on a carcass. Competition between the two species appears to be temperature dependent; *N. orbicollis* finds the highest proportion of experimental carcasses on relatively warm nights, but N. *defodiens* can find and bury carcasses at lower temperatures (Wilson et al. 1984, p. 211). Thus, cool nights are thought to serve as a temporal refuge for coexistence with *N. orbicollis.* Further south, without these cool nights, *N. defodiens* is at a competitive disadvantage (Scott 1998a, p. 599). *Nicrophorus orbicollis* is the most similar congener to the ABB in North America and similar competition could exist between these species. The ABB is slightly larger and can displace *N. orbicollis* at a carcass, but *N. orbicollis* becomes active earlier in the day at dusk and may have an advantage in finding carcasses first.

American burying beetles are nocturnal and must find and bury the carcass in one night. Once an appropriate carcass has been found for reproduction, inter- and intra-specific competition can occur until usually only a single dominant male and female burying beetle remain (Springett 1967; p. 56; Wilson and Fudge 1984, entire; Scott and Traniello 1989, p. 34). Carcasses that become available are not necessarily found and buried immediately by carrion beetles. Complete concealment may take from 2 to 24 h, during which time the carcass could be discovered and appropriated by a competitor (Wilson and Fudge 1984, p. 197; Scott 1990, entire; Scott 1994, p. 370). The ABB typically out-competes other burying beetles as a result of its larger size (Kozol et al. 1988, p. 170). Once the ABB wins the battle for the rights to the carcass, the successful couple buries the carrion, usually in the first night (USFWS 1991, p. 12), copulates, and constructs a brood chamber around the carcass (Figure 2-6), although either sex is capable of burying a carcass alone (Kozol et al. 1988, p. 170).

Figure 2-6. Brood ball with American burying beetle *Nicrophorus americanus* larvae. Photo used with permission. Louis Perrotti Roger Williams Park Zoo. 2008.

Parental care in the genus *Nicrophorus* is unique because both parents participate in the rearing of young (Pukowski 1933, p. 585; Fetherston et al. 1990, entire; Trumbo 1990, p. 9), with care provided by at least one parent, usually the female. Parental care is critical for larval survival (Wilson and Fudge 1984, p. 202). Once underground, both parents strip the carcass of fur or feathers, roll the carcass into a ball and treat it with anal and oral secretions that form a brood chamber and retard growth of mold and bacteria. The female ABB lays eggs in the soil adjacent to the carcass (Pukowski 1933, p. 555; Milne 1976, p. 84; Scott and Traniello 1990, p. 274; Milne and Kozol 1995, p. 16) where the eggs incubate for about 6 days before hatching into altricial larva. Higher temperatures increase egg development rates, reduce incubation times (Damos and Savolpoulou-Soultani 2012), and studies suggest that females reproducing on smaller carcasses produce fewer eggs than females reproducing on larger carcasses (Creighton et al. 2009, p. 681; Billman et al. 2014a, entire; 2014b, entire). Just before eggs hatch and larvae reach the carcass, parents prepare the brood ball by opening a small feeding depression at the top that they treat with regurgitated oral fluids. Brood sizes of ABBs can sometimes exceed 25 larvae, but 12-18 is more typical (Kozol 1990b, entire).

One or both of the parents may remain with the larvae for several days and at least one parent, usually the female, will remain until they pupate (Scott 1990, entire; Kozol 1995, p. 15). Larvae beg and are fed by parents (Pukowski 1933, p 569; Fetherston et al. 1990, p. 184; Smiseth et al. 2003, entire; Leigh and Smiseth 2012, entire), or they can feed directly from the treated carcass. Larvae of large *Nicrophorus* species, are extremely dependent on parental regurgitation and will die before they reach second instar (second stage of larval development) if they receive no parental care (Scott 1998a, p. 602). Additionally, ABBs will cull their brood through cannibalism to increase size and survival of larvae in response to a less than adequately sized carcass (Billman et al. 2014a, entire; 2014b, entire). The reproductive process from carcass burial to eclosure (emergence from pupae) is about 30 to 65 days (Smith and Clifford 2006, p. 11: 31-42 days; Kozol 1995, pp. 2, 99: 55-65 days; Kozol 1988, p. 16: 48-65).

While early research indicated that ABBs reproduce only once per year (univoltine) (Bedick et al. 2004, p. 178), other researchers have found that in a laboratory settings ABBs are capable and successful in producing a second brood during the same season (bivoltine) (Kozol 1990, p. 12; Bedick et al. 1999, p. 3;). ABBs are considered univoltine in the northern portion of their range due to the relatively short active season (Bedick *et al*. 1999, p. 3; Lomolino and Creighton 1994, p. 62). In the southern portion of their range, where temperatures remain suitable for longer durations, adults (F1 generation) may potentially breed twice and their young-of-the year (F2 generation) may breed at least once within the same active season, but data is lacking *in situ* and more research would be needed to confirm or refute this assumption (USFWS 1991, p. 13) but more recent work has shown this may limited by other factors. Recent research showed that *N. orbicollis* stop breeding once temperatures reach about 80 º F and mid-late summer air and soil temperatures could limit potential for reproduction by adults (F1 generation) or young-of-the year (F2 generation) in portions of the ABB range (Curtis Creighton personal comm. July 2016). A more complete discussion is included in Chapter 3, 3.7.2 – Effects to the Species, for climate change. Tenerals can quickly become adults and have successfully bred and reproduced in captive colonies within 2-3 weeks of eclosure (Bob Merze and Lou Perrotti personal communication 2016.) A teneral insect is one that has completed pupation, recently molted and its exoskeleton is yet to harden and get its final coloration. After emerging from the pupa, the adult becomes sclerotized within 24 hours, after which it digs its way out of the subterranean cell (Ratcliff 1996, p. 30).

2.5.2.1 Habitat for Reproduction

While studies indicate that the ABB is a generalist in terms of vegetation types where it is found, it is widely believed they are likely more restricted when using burial sites for breeding

((USFWS 1991, pp. 4, 11; Amaral *et al.* 1997, p. 131). This is observed as burying beetles will often move the carcass several feet (up to 1 meter) to a more suitable soil type or even an abandoned burrow or crack in the soil (Smith et al. 2001, entire). Significant correlations between the numbers of ABBs caught in traps and the biomass of mammals and birds have been observed irrespective of the predominant vegetation (Holloway and Schnell 1997, pp. 148,149,151) suggesting that the vegetation type *per se* is not the key environmental driver for occupation of an area by ABB, but rather the abundance of their reproductive and food resources (small mammals and birds) found within those habitats.

ABBs bury a carcass in the soil for successful brood rearing and reproduction, and soils that are too hard or too compact may limit their ability to create a suitable brood chamber. Likewise, soils that are too loose, such as those with too much sand, will not support the walls of the chamber and, therefore, are also not suitable for brood chambers (Pukowski 1933, p. 523; Milne and Milne 1976, entire; Muths 1991, p. 448). Furthermore, soil moisture has also been found to be a key component of their habitat and is most likely a limiting factor for most burying beetles, especially during drought (Bedick et al. 2006, entire). Therefore, certain soil conditions such as very xeric (dry), or loose soils, sandy soils, and highly saturated soils, are generally accepted to be unsuitable for carcass burial and thus are unlikely reproductive habitats (Bedick et al. 2006, entire; Abbott and Abbott 2013, p. 7). In Oklahoma, Lomolino and Creighton (1996, entire) found reproductive success was higher in forest verses grassland; nevertheless, of the carcasses buried in the two different vegetation types, brood size did not seem to be influenced by vegetation characteristics (Lomolino and Creighton 1996, p. 238-240). In the southern portion of their range, ABBs occur in forests with substantial litter layers and deep, loose soils as well as grasslands and bottomland forests where the substrate is conducive for carcass burial (Creighton et al. 1993, entire; Lomolino and Creighton 1996, entire).

2.5.3 Genetics

Earlier genetic studies found no evidence to suggest that any populations should be treated as separate, genetically independent conservation segments. Kozol *et al*. (1993, entire) examined ABB genetic variation to compare the Block Island population and the eastern Oklahoma and western Arkansas population. At that time, both populations were found to have low levels of genetic variation, and most of the variation occurred within a single population. There were no unique diagnostic bands within either population, but they found the Oklahoma-Arkansas population to be somewhat more diverse. Reduced genetic variation is often a result of founder effect, genetic drift, and inbreeding. Kozol *et al*. (1994, p. 933,) suggested, based on entire works by Waller *et al*. 1987, Lacy 1987, and Packer *et al* 1991) that multiple bottleneck events, small population size, and high levels of inbreeding may be factors contributing to the pattern of genetic variation in ABBs.

Expanding on Kozol *et al*.'s 1993 study, Szalanski (2000, enitre) compared ABB DNA from five populations: Block Island in Rhode Island, Arkansas, South Dakota, Oklahoma, and Nebraska. The authors found little evidence that the five populations had unique genetic variation, and no evidence to suggest that these five populations should be treated as separate, genetically independent conservation segments. There is recent evidence suggesting that the New England population may represent a genetically distinct population as compared to western populations (Patricia Parker – personal communication, September 19, 2015). The University of Missouri researchers, in cooperation with the St. Louis Zoo suggest that although the two areas are distinct, they appear to share some genotypes. However, geographic isolation between the two areas will likely continue to differentiate them further, making them more distinct over time. The researchers also examined differences between northern and southern areas, but no clear genetic distinctions were observed. However, samples did not represent all areas of the northern or southern range and samples representing additional natural populations would provide greater support for this conclusion (Rois 2015). Regarding overall genetic diversity, high genetic variability exists in both the eastern and western areas (Patricia Parker – personal communication, September 19, 2015).

2.5.4 Defining Populations as Analysis Areas

The SSA is not using the same four broad geographical areas as the Recovery Plan because we believe those areas may not adequately represent genetic or ecological diversity (also called environmental variation or diversity) within and among populations. For example, most of the areas used in the Recovery Plan represent only northern or southern regions, but the Midwest area is very large and encompasses all western populations from the gulf coast to the Canadian border. It is comprised of northern and southern populations that may represent different ecological diversity. The ABBs in the southern areas are not currently known to have unique genetic characteristics, but differences between northern and southern populations of ABBs and congeners in reproductive and overwintering studies (Wyatt Hoback and Curtis Creighton personal communications 2016), may represent regional adaptations to warmer climates. We have made the assumption that differences in ecological diversity are more likely to evolve due to difference in latitude than any based on longitude.

The SSA evaluates the current and future status of known populations based on analysis areas that are based on recent known records of ABBs. These analysis areas are defined below and were evaluated for their representation of the genetic or ecological diversity that is currently available and what was potentially represented historically.

We generally refer to ABB populations as clustered, localized areas, roughly defined by habitat differences or other geographical features, with inter-breeding ABB individuals. However there are no clear boundaries separating many of the areas known to be occupied by ABB. So for the purposes of this analysis we've organized the current range of the ABB into analysis areas that follow broad geographic and ecological patterns (Figure 2-7). This is the scale of "populations" referred to in the analysis of risk factors potentially affecting the species (Chapter 4). Thus far, limited genetic analysis of individuals from across the species' range have identified little genetic structuring between these populations, presumably indicating that historically there has been regular gene flow between these populations. There is recent evidence suggesting that the New England population may represent a genetically distinct population as compared to western populations (Patricia Parker – personal communication, September 19, 2015). More complete genetic information is provided in Chapter 4, section 4.7.2. In some cases there is no distinct geological feature separating analysis areas, but there can be differences in risk factors related to land uses, human population concentrations or other factors.

These analysis areas were designated based on capture of ABBs since 2001. As a coarse estimate, we included an 18.6 mi (30 km) buffer around each capture location, which is based on flying capabilities, to determine the outside boundaries of analysis areas. Boundaries between analysis areas are based on current ABB survey information and/or natural or man-made boundaries. The analysis areas are not intended to imply a high probability that the ABB occurs throughout these areas, but are used as a framework for conducting this analysis.

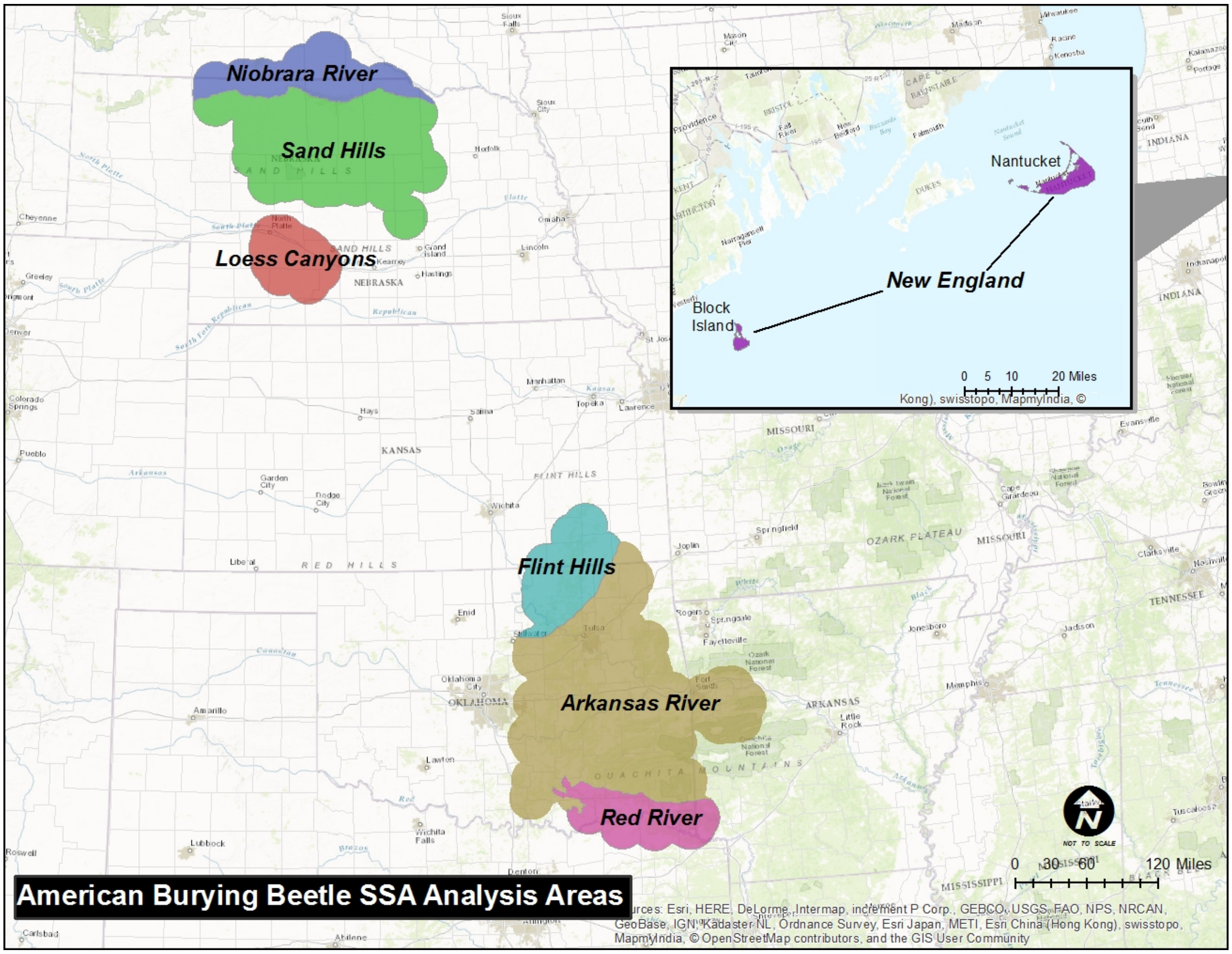


Figure 2.7 American burying beetle analysis areas for the SSA report.

The Niobrara River was used to designate the boundary between the Niobrara River and Sandhills analysis area, which separates the two areas. The Flint Hills/Arkansas River boundary was designated by assessing the distribution of ABB survey information, which clearly shows a demarcation (from east to west) where positive surveys are limited, thus creating some level of separation between the two areas. The boundary between the Arkansas River and Red River analysis areas was designated using the Level III Ecoregional boundary, referred to as the South Central Plains. A brief description of each analysis area is provided in Table 1-1 below.

Table 1-1. Analysis Areas used to analyze risk factors and current and future conditions.

Geographic Area	Analysis Area	Total Acres	General Description
Southern Plains	Red River	3,251,894	The flood plain of the Red River and areas with more level topography and suitable soils support relatively large areas of agricultural row crop, hay, or pasture lands. Where terrain is mixed, bottomland hardwood forests, mixed hardwood and evergreen forest and commercial timber (mostly pine plantations) operations dominate these areas.
	Arkansas River	17,753,431	Multiple ecoregions represented with diverse land cover types and habitat that ranges from old mountains to prairies. Large portions of the analysis area are dominated by a mixture of forest types whereas other portions are dominated by grassland/pasture lands with some trees and shrub cover. Cropland makes up a small portion of the area and although urbanization is greatest in the analysis area, it represents a small portion of the overall area.
	Flint Hills	3,706,908	Three Level III ecoregions are represented in this area, which is dominated by grassland and pasture, followed by trees and shrub cover, and to a lesser extent croplands. Urbanization represents a small portion of the area, comprised of multiple small urban areas.
Northern Plains	Loess Canyons	2,759,065	The Central Great Plains ecoregion is represented in this area in which grasslands and pasture make up nearly half of this area, with croplands making up nearly one third and to a much lesser extent scrublands followed by mixed forest. Urbanization represents only a small portion of the area, comprised of multiple small urban areas.
	Sandhills	10,819,170	The majority of this area is comprised of the Sandhills Ecoregion, in which grassland and pasture with intermixed trees and shrub cover make up the majority of this area, followed by cropland and mixed forest. Urbanization represents only a small portion of the area, comprised of multiple small urban areas.
	Niobrara River	4,108,903	Three Level III ecoregions are represented in this area in which grassland and pasture with intermixed trees and shrub cover make up the majority of this area, followed by cropland and mixed forest. Urbanization represents only a small portion of the area, comprised of multiple small urban areas.
New England	Nantucket and Block Islands	42,432	Block Island is 6,111 acres in size, and Nantucket is 36,321 acres in size. Combined there is a total of 42,431 acres with 25,865 suitable habitat acres and 14,457 acres of protected lands. Habitat is a mixture of grassland/shrubs with small areas of forest. Urban and residential areas are a significant portion of Block Island.

CHAPTER 3: RISK FACTORS

3.1 INTRODUCTION

The American Burying Beetle Recovery Plan (USFWS 1991) and the 5-year Status Review of the species (USFWS 2008a) identify the following factors as potential threats to ABB: direct habitat loss and alteration, increase in competition for prey, inter and intra-specific competition, increase in edge habitat, decrease in abundance of prey, loss of genetic diversity in isolated populations, disease/pathogens, DDT, agricultural and grazing practices, and invasive species. None of these factors alone adequately explain why ABBs declined over much of their historic range, while congeneric species remain relatively common range wide [there are eight sympatric congeners which are not in peril (Sikes and Raithel 2002, entire)].

The prevailing theory regarding the ABB's decline over a large portion of their historical range is habitat change (USFWS 1991, p 20, Sikes and Raithel 2002, entire) which: (1) reduced the carrion prey base of the appropriate size for ABB reproduction, and (2) increased the vertebrate scavenger competition for this resource (Kozol 1995, p 170; Lomolino and Creighton 1996, entire; Ratcliffe 1996; Amaral et al. 1997, p. 123–124; Bedick et al. 1999, p. 179; Creighton et al. 2009, p. 40). Although much of the evidence suggesting the reduction of carrion resources as a primary mechanism of decline is circumstantial, this hypothesis fits the temporal and geographical pattern of the disappearance of ABBs, and is sufficient to explain why ABBs declined while related species did not.

Potential risk factors or threats are discussed below and listed by analysis area in Table 3-1. All of the potential threats identified in the recovery plan and some additional threats are addressed in the remainder of this chapter, but these potential risk factors are not equal in all portions of the ABB range. This chapter is an overview of the potential risk factors and additional discussions of for each analysis area are covered in Chapters 4 (Current Conditions) and 5 (Future Conditions and Viability)

3.2 HABITAT LOSS AND ALTERATION

Due to the ABBs relatively large size and specialized breeding behavior (Creighton et al. 2009, p. 37) the prevailing theory regarding the ABBs' decline has been habitat loss and alteration or vegetative alteration (USFWS 1991, p 20, Sikes and Raithel 2002, entire) which reduced the carrion prey base of the appropriate size for ABB reproduction, and increased the vertebrate scavenger competition for this prey (Kozol 1995, p 170; Ratcliffe 1996, Lomolino and Creighton 1996, entire Amaral et al. 1997, p. 123–124; Bedick et al. 1999, p. 179; Creighton et al. 2009, p. 40). In a fragmented ecosystem, larger species have been shown to be negatively affected before smaller species, a phenomenon that has been well-documented with carrion and dung beetles in South America (Klein 1989, entire).

There is little doubt that habitat loss and alteration affect this species at local or even regional levels, and could account for the extirpation of populations once they become isolated from others (Kozol 1995, p 170; Ratcliffe 1996, Lomolino and Creighton 1996, entire Amaral et al. 1997, p. 123–124; Bedick et al. 1999, p. 179; Creighton et al. 2009, p. 40). For example, there are no known ABB populations surviving in intensively farmed or highly urbanized areas. Portions of the historical and current ABB range have experienced substantial habitat loss (such as urban development and roads) or vegetative alterations (such as intensive row cropping and grazing). Projects that my cause ABB habitat loss or reduce habitat suitability are common. As a part of administering the Endangered Species Act the Service is asked to review numerous proposed projects that may have impacts to the ABB. Projects evaluated include pipelines, roads, quarries, communication towers, residential housing development, bridges, mining, petroleum production, commercial agricultural and recreational development, transmission lines, and water and wastewater treatment facilities. Impacts from these activities vary in size and duration, with projects such as quarries with hundreds of acres of permanent impacts (although limited in overall number of projects), to pipeline projects that may result in temporary impacts to habitat and because of their linear nature may be a relatively small in total area impacted. The majority of the projects were small and very few have large and permanent impacts.

Some types of land uses are relatively common in portions of the Southern Plains analysis areas, but rare in the remainder of the existing ABB range. For example, oil and gas development can have local impacts to habitat in portions of the Southern Plains analysis areas, but is relatively uncommon in other analysis areas. Oil and gas development can be significant in some areas, but minor compared to agriculture or urban expansion in the entire Southern Plains analysis areas. In Oklahoma, an Industry Conservation Plan (ICP) was developed to streamline ESA compliance for the oil and gas Industry. Approximately 32,000 acres of oil and gas related soil disturbance were estimated to occur (between 2014-2016, within the potential ABB range in Oklahoma), but the actual rate has been much less and a large percentage is considered temporary. The ICP covers most of the combined Red River, Arkansas River, and Flint Hills analysis areas. To date (about 3 years), 355 acres of occupied or assumed ABB habitat have been permanently impacted by activities covered in the ICP, 601 acres have been converted to another habitat type (e.g., from forest to grassland) still suitable for the ABB, and 1,457 acres impacted temporarily (restored to suitable ABB habitat within five years). Over 1,800 acres of permanent mitigation has been established at two conservation banks through the ICP. At this rate, approximately 3,550 acres would be permanently impacted over a 30 year period. However, oil and gas activity has been relatively low during those three years and may not represent future conditions. If we assume a rate of 10,000 acres of habitat loss over a 30 year period (about 3 times the recent rate), the loss of approximately 30,000 acres could occur by 2099. This is less than 1% of the suitable habitat in the Southern Plains analysis areas.

Land conversion to agriculture, intensive domestic livestock grazing, logging, fire suppression, wind energy development and urban development are common causes of habitat loss and fragmentation within the current ABB range. For example, large areas of native grasslands have been converted to introduced non-native grasses such as fescue and bermuda grass varieties to improve pastures for intensive cattle grazing operations. Even in areas with native vegetation, pastures and hay fields can be more intensely grazed or mowed during drought periods when demand for grass/hay is high, which can keep habitat in an unfavorable or marginal condition for longer time periods.

Agricultural and forestry/silvicultural industry practices can make some areas unsuitable or marginal for ABB use. For example, lands used for row crops may provide some seasonal ABB habitat, but are frequently tilled and maintained in a relatively barren landscape for periods of time when crops are harvested and before newly seeded crops have grown. Some crops also require use of pesticides that could adversely affect ABBs. Large contiguous areas of row crops provide poor habitat for potential carrion species ABBs rely on and this probably accounts for very few positive ABB survey results in areas dominated by row crops.

Intensive silviculture with pine plantations has a similar effect on ABB habitat and is essentially using trees as a row crop. In intensive silviculture management, a plantation is harvested via a clear cut and then replanted with seedlings. New clear cuts can support high rodent numbers for several years, but in some cases the competing vegetation is controlled with herbicides and/or mowing to enhance survival and growth of the young trees. Young pines are planted close together so that they tend to shade out other vegetation as they grow larger, and areas with dense pine canopy tend to be poor habitat for potential carrion species and ABBs because the plantation has a low diversity of vegetation with very limited food resources for potential carrion.

Since European settlement, fires have been largely suppressed in much of the ABB range, leading to changes in community types and species composition. The suppression of fire has allowed an expansion of woody vegetation in most of the ABB's current range (Ratajczak et al. 2012, entire). The expansion of invasive woody species like eastern red cedar has reduced Grassland and savanna habitats and increased the canopy cover in forested habitats (New, 2012, p. 1). Riparian areas and bottomland habitats have been severely degraded not only as a result of conversion to agriculture and logging, but also because of inundation by numerous reservoirs (Wells 2007, pp. 18–27). The anthropogenic breakdown of barriers to dispersal also has permitted the invasion of non-indigenous species (Northern Prairie Wildlife Research Center

2006) such as johnsongrass (*Sorghum halepense*), Russian olive (*Elaeagnus augustifolia*), saltcedar (*Tamarix ramosissima*), and *Sericea lespedeza*.

The effect of vegetative alterations on habitat use and suitability for ABBs is difficult to measure on a large scale with existing data and survey methods. Databases for land use may identify areas as rangeland or pastureland, but do not provide information on the current level of grazing or habitat conditions of those grazed areas. Habitat quality can vary within and between pastures, and years, in grazed grassland or savanna habitat.

The use of land for grazing and other agricultural activities typically results in vegetation changes that reduce numbers of relatively large rodents (Lovejoy et al., 1986, pp. 276–277), such as hispid cotton rats *Sigmodon hispidus* (100-225g in samples from Fort Chaffee, Arkansas), which are of optimal feeding and breeding size for the ABB (Holloway and Schnell 1997, page 151) in Southern Plains analysis areas. Generally, increases in farming and ranching alter vegetation in ways that support larger numbers of small rodents, such as deer mice, which can be fed on by ABBs, but are probably too small (i.e. only 15-25 g) for them to use successfully when breeding (Holloway and Schnell 1997, page 151). Heavily grazed habitat in Southern Plains analysis areas tend to be poor habitat for most birds and rodents that are potential carrion and have low or no positive ABB surveys. Southern analysis areas with no grazing or light-moderate grazed habitat with taller vegetation can be favorable habitat with good ABB catch rates.

Grazing in the Nebraska and South Dakota analysis areas does not seem to have the same negative effect on ABB numbers or presence. Potential carrion sources in Northern Plains analysis areas may be adapted to shorter grasslands. The grasslands in the Northern Plains analysis areas receive about half the annual precipitation compared to the Southern Plains analysis areas and the native grasslands in the Northern Plains analysis areas are shorter. These mid-grass prairies support different potential carrion species that are adapted to shorter grasses (see section 3.3 below). Also, grazing on the sandy soils in the Northern Plains analysis areas may not compact soils as much as grazing in Southern Plains areas with more clay in the soils. Soil compaction may affect the growth of vegetation and the ability of ABBs to bury a carcass.

The ABB uses a variety of habitats and habitat quality may be a function of its ability to support appropriate and available sources of suitable carrion for reproduction (USFWS 1991, p 16–24). Some vegetation alterations, such as prescribed fires, are natural and may enhance habitat for some sources of carrion and ABBs. Additional discussions of habitat loss and alteration are included for specific analysis areas in chapters 4 and 5. Habitat loss and alterations related to current conditions and potential future conditions for each analysis area are addressed in these chapters.

3.3 AVAILABILITY OF CARRION

The ABB's uneven distribution and density, and the significant decline of their distribution are likely due to the species having specialized resource requirements with carrion being a finite resource that is widely scattered in space and time (Karr 1982, p 233; Pimm et al. 1988, p 757, 776–777; Peck and Kaulbars 1987, p 55). Data available for the ABB on Block Island, Rhode Island supports the contention that the primary mechanism for the species range wide declines "lies in its dependence on carrion of a larger size class relative to that used by all other North American burying beetles, and that the optimum-sized carrion resource base has been reduced throughout the species range" (USFWS 1991, p 21; Peck and Kaulbars, p 55). Since the middle of the 19th century, certain animal species in the favored weight range for ABBs have either been eliminated from North America or significantly reduced over their historic range (USFWS 1991), including the passenger pigeon (*Ectopistes migratorius*), Carolina parakeet (*Conuropsis carolinensis*), greater prairie-chicken (*Tympanchus cupido*), bobwhite quail (*Colinus virginianus*) and wild turkey (*Meleagris gallopavo*) to name a few. The passenger pigeon was estimated at one time to have been the most common bird in the world, numbering 3 to 5 billion (Ellsworth and McComb 2003, p 1549). There were once as many passenger pigeons within the approximate historic range of the ABB as there are numbers of birds of all species overwintering in the United States today. Young wild turkeys are briefly at a suitable size during the active season, occurred throughout the range of the ABB, and until recently, were extirpated from much of their former range. Black-tailed prairie dogs (*Cynomys ludovicianus*) which occur in the Northern Plains analysis area have drastically declined (Miller et al. 1990, p 763) and based on the extent of overlap between the prairie dog's initial range and that of the ABB, previously dense populations of prairie dogs may also have supported ABBs.

Availability of appropriate-sized carcasses is important for ABB reproduction and reduced availability of appropriate carcasses is the leading hypothesis for the historical decline in ABB distribution. Carcasses must be large enough to provision larvae, but small enough for two adult beetles to bury, prepare and they must be located on or near soils suitable for burial and construction of an underground brood chamber. Adult ABBs may feed on carcasses of any size, but ABBs prefer to use carcasses of approximately 80-200 grams for reproduction and have been documented to use a variety of carrion for this purpose (including fish, reptiles, mammals, and birds). Smaller carcasses can be used by ABBs, but smaller carcasses support fewer larvae (decreases fecundity), are used by several other congeners (increases competition), and are more quickly consumed by flies and other carcass scavengers. Carcasses that are too large for reproduction are difficult to bury and too large for the adults to prepare and maintain (control competing fly larvae, cover with secretions to control decomposition and fungus).

ABBs are known to use a variety of carrion, but it is not known what species are the primary sources of carrion for ABBs in the different analysis areas. Carrion availability for ABB reproduction may be associated with different species of birds and small mammals in different areas of the ABB's range. Many species of birds and small mammals are known to fluctuate or cycle in abundance due to changes in weather, vegetation succession, predator/prey balances and competition. The fluctuations in abundance of potential carrion species could affect the availability of suitable carrion for ABB reproduction. Schnell et al. (2006, entire) reported that areas of high ABB concentrations appeared to shift annually throughout Fort Chaffee, Arkansas and Camp Gruber, Oklahoma, even though land use within each area stayed relatively stable (USFWS 2008b, p. 14). These shifts in ABB concentrations could be related to shifts in carrion availability and Holloway and Schnell (1997, p. 151) documented that areas with higher catch rates of ABBs corresponded with areas with greater abundances of small mammals and birds at Fort Chaffee. Significant correlations were found of the number of ABBs caught with biomass of 0-200 g mammals; biomass of mammals plus birds; numbers of species of mammals; and numbers of individual mammals. American burying beetles frequented sites where small vertebrates (particularly mammals) were relatively abundant, irrespective of the predominant habitat at that site. However, all of the areas with the highest ABB catch rates were in grasslands or open forest with a grass component (Schnell and Hiott, 2005, p. 3). There was no relationship between the number of beetles and the biomass of 0-200 g birds (Holloway and Schnell 1997, p. 151).

Schnell et al. 2014 (pp. 178–180) researched potential carrion and ABB relationships at Camp Gruber in Oklahoma during the summer of 2003. Eighty seven sites were surveyed for beetles (baited pitfall-traps), birds (modified point-count transects), and mammals (Museum Special snap-traps and rat traps), finding significant rank correlations of number of ABBs with number of species of birds, number of individual birds, and biomass of birds but not with similar measures for mammals. Combined biomass of birds and mammals was significantly associated with number of beetles. Path analysis, considering four possible direct influences of measures for vertebrates on beetles, indicated number of beetles was directly and positively affected by biomass of birds and biomass of mammals and inversely by number of individual mammals, while number of individual birds was unrelated to numbers of beetles. Beetles tended to be at sites with fewer but larger mammals that were near 200 grams. Path analysis provided the most informative assessment in that variables potentially influencing beetle numbers were considered simultaneously. While results for Camp Gruber were not identical to those of a similar study at Fort Chaffee, Arkansas, both indicated ABB was more likely in places frequented by vertebrates. The association might be due to beetles being attracted to places with more vertebrates because carcasses likely were more abundant; alternatively, suitable environmental conditions may attract vertebrates and ABBs. Also, beetles may have increased reproductive success at such sites. Lack of covariation of numbers of avian and mammalian species at sites strengthens the supposition of beetles being attracted to sites because of birds and mammals found there.

The carrion sources may be different for different analysis areas. Carrion sources specific to the ABB are unknown, but significant correlations between the numbers of beetles and the numbers and biomass of <200-g birds or <200-g mammals has been documented at some sites. Carrion sources for ABBs in portions of the Southern Plains analysis areas appear to be mostly mammals, such as at Ft. Chaffee in Arkansas (Holloway and Schnell 1997, p. 151) or a mixture birds and larger rodents at Camp Gruber (Schnell et. al 2014, page 178). At Block Island, carrion sources are presumed to be birds, as there is no significant population of the appropriate size mammals on the island (Raithel 2002, p. 198). Relative to the Southern Plains analysis areas, the Northern Plains analysis areas support different potential carrion species such as pheasants, prairie chickens, sharp-tailed grouse, prairie dogs, ground squirrels and several species of migratory birds that nest in Nebraska and South Dakota, but only migrate through Oklahoma, Kansas and Arkansas.

3.4 COMPETITION WITH MESO-CARNIVORES

During the westward expansion of settlement in North America, the removal of top-level carnivores such as the grey wolf (*Canis lupis*) and eastern cougar (*Puma concolor*) occurred simultaneously with land use changes that fragmented native forests and grasslands and created more edge habitats (such as the edge between forest and grassland, or grassland and cropland). These two processes, (extirpation and fragmentation) resulted in meso-carnivores (mid-sized) becoming more abundant (Gipson and Brillhart 1995 pp. 305–307; Garrott et al. 1993, p. 946–949, Wilcove et al. 1986, p. 248-249). Meso-carnivores prey on small mammals and birds and directly compete with carrion beetles for carrion.

Fragmentation of large contiguous habitats into smaller pieces or patches of habitat may increase species richness, but the species composition usually changes. Fragmentation of forests and grasslands cause a decrease of indigenous species and a corresponding increase in meso-carnivores that thrive in areas disturbed by humans such as: American crow (*Corvus brachyrhynchos*), raccoon (*Procyon lotor*), red fox (*Vulpus fulva*), opossum (*Didelphis virginiana)*, striped skunk (*Mephitis mephitis*), coyotes (*Canis latrans*), feral cats (*Felis domesticus*), and other opportunistic predators (Wilcove et al. 1986, p. 248-249).

This fragmentation facilitated increased competition for limited carrion resources among the "new" predator/scavenger community. A number of these species, especially the raccoon and striped skunk, have undergone dramatic population increases over the last century (Garrott et al. 1993, p. 946), and the coyote and opossum have expanded their range. These scavengers may extend hundreds of feet from edges into forest in eastern North America. Matthews (1995, p. 19) found that a high percentage of carcasses are claimed by ants, flies and vertebrate scavengers (83%). DeVault et al. (2011, entire) investigated the fate of mouse carcasses in an intensively farmed region in Indiana, USA, using remote cameras. Vertebrates removed 234 of 266 (88%) carcasses within two weeks after placement. Raccoons (Procyon lotor) and Virginia opossums (*Didelphis virginiana*) were the predominant scavengers, removing 184 of 197 (93%) carcasses for which a scavenger could be identified. Air temperature influenced carcass removal by vertebrates only at higher temperatures, with fewer carcasses removed as temperatures increased over 22 degrees C. Elevated densities of mesopredators, coupled with the reduced search area for carrion due to the sparse distribution of habitat, likely were responsible for the rapid discovery and high level of carcass removal by vertebrates compared to previous investigations. They suggested that in agricultural landscapes, the competitive balance for carrion can differ substantially from that found in more pristine habitats and abundant mesopredators may have negative consequences for other species that use carrion.

3.5 INTER AND INTRA-SPECIFIC COMPETITION

For most guilds (a group of species that utilize similar resources), larger species tend to feed on larger prey, occupy a greater diversity of habitats, dominate in interference competition, and maintain larger home ranges, but may suffer from exploitative competition from smaller species (Ashmole 1968, entire; Gittleman 1985, entire; Hespenheide 1971, entire; Rosenzweig 1968, entire; Schoener and Gorman 1968, entire; Werner 1974, entire; Wilson 1975, entire; and Zaret 1980, entire). While large size alone does not necessarily confer endangerment, rarity and extinctions tend to be higher for larger species within trophic levels or guilds (Diamond 1984; Martin and Klein 1984; Vrba 1984; Owen-Smith 1988; and Stevens 1992). Although less than two grams in weight, the ABB is nonetheless the largest member of a guild that specializes on vertebrate carcasses, a rare and unpredictable resource. Larger prey is less abundant than smaller prey (Peters 1983, Brown and Maurer 1987, p. 9; Damuth 1991, and Lawton 1990) and larger guild members require larger home ranges (Brown and Maurer 1987, p. 9). In contrast to other members of the necrophore guild, the ABB may range over a larger area and a greater diversity of habitats to find suitable carcasses.

In addition, larger carcasses are harder to bury than smaller ones (Creighton et al. 2009, p. 38) enabling vertebrate scavengers extra time to steal the carcass from the insects. ABBs are the largest species of burying beetle in the New World (Western Hemisphere) and require carcasses of 3.5 to 7.0 ounces (80 to 200 g, Kozol et al. 1988, p. 13) to maximize its fecundity, whereas all other burying beetles can breed abundantly on much smaller carcasses, with the smaller species using carcasses as small as 0.11 to 0.18 ounces (3.12 to 5.10 g, Trumbo and Fiore 1994, Table 2, p. 172).

Size appears to be the most important determinant of success in competition for securing carrion; the largest individuals displace smaller burying beetles (Kozol et al. 1988, p. 18). ABBs have been recorded as commandeering a carcass that has been buried by another burying beetle species. However, factors other than size (e.g., temperature or activity patterns) might also affect the outcome of competition (Wilson and Fudge 1984, p. 200) because competition for carrion from other burying beetles species (i.e., congeners) increases with carcass size (Trumbo 1992, p.

293,) and carrion-feeding flies were found to be a large competitor as well (Scott et al. 1987, Table 1, p. 329; Trumbo and Fiore 1994, p. 173). Habitat fragmentation (and increase in edge habitat) causes increased vertebrate and invertebrate scavenger pressure, which decreases availability of carrion of the appropriate size, and increases competition between burying beetles (Creighton et al. 2009, p. 40–42). As ABB populations decline, the competition between ABBs and sympatric congeners for sub-optimally sized carcasses would be expected to increase.

Habitat changes that favor smaller carrion sources may indirectly benefit congeners/competitors that can use smaller carcasses. Generally, vegetation changes associated with farming and ranching are accompanied by larger numbers of small rodents, such as deer mice, which can be fed on by ABB, but are probably too small (i.e. only 15-25 g) for them to use successfully when breeding (Holloway and Schnell 1997, p. 151)

Studies based on habitat preferences of vegetation or statewide physiographic regions have shown niche partitioning among Nicrophorinae by latitudinal distribution (Anderson and Peck 1986, entire; Peck and Kaulbars 1987, entire), seasonal and diurnal activity patterns (Shubeck 1971, entire; 1983, pp. 45-46), and mass of carrion resource (Sikes and Raithel 2002, p 11; Schnell et al. 2014, p. 178). Research has investigated habitat partitioning showing soil, vegetation, air temperature, and soil types and moisture as factors influencing habitat associations with *Nicrophorus* species (Scott, 1998, pp. 596, 597-600; Bishop et al., 2002, entire; Bedick et al. 2006, p 28). Soil texture may be important to *Nicrophorus* species as well (Muths 1991, entire; Scott, 1998 – p. 599, Bishop et al. 2002, entire). Niche partitioning by soil texture among some burying beetles has been described, but for those species where their occurrence overlaps, niche partitioning may also be due to other factor(s) besides soil texture (Bishop et al. 2002 – p. 463). Additionally, *Nicrophorus* habitat preferences have been repeatedly tested for niche partitioning (Anderson 1982, entire; Shubeck 1983, entire; Peck and Kaulbars 1987, entire; Creighton et al. 1993, entire; Lingafelter 1995, entire) and these partitions and changes that favor competing species could help to explain declines in the ABB across its historical range (Lomolino and Creighton 1996, entire).

Habitat or vegetation changes can also affect the abundance and diversity of competing congeners. For example, both *N. orbicollis* and *N. marginatus* are relatively large congeners that can compete with ABBs for carrion, but *N. orbicollis* is a forest specialist and *N. marginatus*, a grassland specialist (Lomolino et al. 1995, p. 611; Lomolino and Creighton 1996, pp. 238–240; Backlund and Marrone 1997, Table 2, p. 56). Succession and invasion of woody vegetation has been documented in many areas of the ABB range (attributed largely to fire suppression) and would favor the expansion of *N. orbicollis*.

The ABB's most similar and closely related congener is *N. orbicollis*. The figure at right shows a photograph taken for comparison between *N. orbicollis*, and *N. americanus*. Based on the historical geographic range, the ecological tolerances (e.g., diel periodicity, breeding season), and phylogenetic information indicates these species may be each other's closest surviving relatives (Szalanski et al. 2000, entire). Being so similar, they likely are each other's greatest congeneric competitors (Sikes and Raithel 2002, p. 109), and interspecific competition may affect populations at the local level. Typically, surveys for ABBs result in at least 10 times (or more) more *N. orbicollis* than ABBs (Walker 1957, Table VII, p. 273; Lomolino and Creighton 1996, p. 238; Amaral et al. 1997, p. 128; Carlton and Rothwein 1998, p. 183; Sikes and Raithel 2002, p. 109.) While the ABB is more successful than *N. orbicollis* in utilizing carcasses greater than 100 g, these data suggest that *N. orbicollis* may be a formidable competitor for the ABB (Sikes and Raithel 2002, p. 109) and may have actually increased (have been released from competition) in those areas where ABBs disappeared (USFWS 1991). In addition, *N. marginatus* may also be a formidable competitor to ABBs. *N. marginatus* is on average slightly larger and utilizes larger carcasses than *N. orbicollis* and in prairie states is typically more abundant (Backlund and Marrone 1997, Bedick et al. 1999). *N. carolinus* is another large congener that may compete with ABBs in portions of the range Bedick et al. 1999, p 179). Increased temperatures and drier conditions may make congeners like *N. carolinus* more competitive and reduce or eliminate *N. americanus* in southern and western populations. The decline of ABB and the increase in *N. carolinus* in Texas could represent these effects (Abbott and Abbott 2013, entire. Another threat to ABB reproductive success is brood parasitism after the oviposition by other burying beetle species near an ABB buried carcass (Müller et al. 1990, Trumbo 1994, entire). Trumbo (1992, p. 295) found that mixed species burying beetle broods were more common on larger carcasses.

Invasive species can also be competitors for carrion. The imported fire ant (*Solenopsis invicta* – RIFA) has become a formidable competitor for carrion and a potential source of mortality for burying beetles when they co-occur at a food or reproductive resource (Godwin and Minich 2005, p. 9). RIFA are attracted to wildlife species nesting under or on the ground and in low trees. Species that breed and live in open habitats are more vulnerable than species living in closed-canopied habitats, which tend to have much lower fire ant densities. RIFA are omnivorous, feeding on both animal and plant material. However, insects appear to be their preferred food source (Wilcox and Giuliano 2006, p. 3). Scott et al. (1987, pp. 327–328) concluded that the inability of *N. carolinus* (similar in size to the ABB) to successfully bury carrion provided experimentally in Florida was due to interference by imported fire ants. Only 5 of 48 carcasses were successfully exploited by N. carolinus, despite pitfall trapping that demonstrated that N. carolinus was locally abundant. Fire ants may reduce ground-nesting populations of rodents and birds, and in some instances, may completely eliminate ground-nesting species from a given area (Collins and Scheffrahn 2005, Wilcox and Giuliano 2006, p. 4). Fire ant infestations are not evenly distributed; rather, they tend to be more numerous in open, disturbed habitats (Gleim et al. 2013, pp. 270, 271). Of the states containing populations of ABB, fire ants are known to infest all or parts of Arkansas, Oklahoma, and Texas (USDA 2003, online).

The degree of fire ant-related effects on ABB is not clear, and while it is unlikely that competition and mortality related to fire ants alone would cause the extirpation of ABBs directly, insects appear to be fire ants preferred food source (Wilcox and Giuliano 2006, p. 3). Additionally, fire ants have been found to significantly reduce the foraging behaviors of cotton rats (Darracq et al. 2016, p. 1) as well as affect bobwhite quail chicks (Giuliano et al. 1996, entire) in areas where they co-occur. Both of these animals are widely believed to support ABB reproduction in various parts of its range. Some areas in northern Texas (Camp Maxey) and southern Oklahoma have documented populations of ABB in areas that have had fire ants for decades, but these areas have more recently experienced local ABB extirpations. Schnell et al. (2006, pg. 3-4) noted an increase in the number of fire ant mounds near trap sites in 2005, on the Weyerhaeuser HCP planning area in McCurtain County, Oklahoma, and Little River County, Arkansas, but the decline in ABB captures began several years prior to 2005. Fire ants have been been present in variable densities for more than 15 years in many areas of southern Oklahoma that still currently have relatively high ABB catch rates. We understand that land use affects ABB populations at various scales, but it is more difficult to disentangle the adverse effects of intensive land management, such as clear cutting forests, from the subsequent adverse effects of fire ant invasion following disturbance, as well as climate change in areas where all these factors are culminating in the alteration of ABB habitat. Further study would be needed to disentangle these effects on ABB. While similar congeners like *N. carolinus* and *N. orbicollis* continue to occur in good numbers in areas with fire ant co-occurrence, it is unknown if these cohorts have additional strategies beyond what ABB possess, or phenology differences that allow them to better cope with these adverse effects.

3.6 LOSS OF GENETIC DIVERSITY

Descriptions of existing genetic studies are provided in Chapter 2, (2.5.3). The species occurs in a wide range of ecological conditions and it is unknown if any particular setting is more important than another. Therefore, we assume that we can best reduce the risk of loss of any unidentified genetic or ecological diversity through maintaining a broad distribution of the species across its range. We are measuring this distribution indirectly through the spatial analysis of occupied habitats. The broader the distribution of these habitats, the higher the overall representation of the species and the more the adaptive potential for the species can be maintained.

Additional genetic study is needed to determine if the loss of genetic diversity is affecting or limiting ABB populations, but there is no existing evidence to support this as a risk. Isolation and fragmentation of ABB populations in the future could reduce or eliminate genetic exchange within and between populations and cause a loss of genetic diversity over time. The New England population of ABBs has been isolated from other populations for decades. This population may have unique genetics and reintroductions at other locations like the Nantucket Island site would help maintain the genetic diversity represented by this population.

3.7 DISEASE/PATHOGENS

A pathogen hypothesis could account for the ABBs pattern of decline. Any pathogen that could be transmitted among adult burying beetles, and was non-fatal to congeners of ABB could affect or eliminate most contiguous ABB populations, and leave only peripheral isolated populations intact (Sikes and Raithel 2002, p. 102). Raithel (in US Fish and Wildlife Service (1991, p.18) suggested this hypothesis and also pointed out that no evidence of a disease or pathogen had been found. However, there has been only limited investigation to test this hypothesis. As reported by Sikes and Raithel, (2002, p. 106) a phylogenetic analysis by Peck and Anderson (1985, entire), found that the ABB was phenotypically and evolutionarily distant from New World *Nicrophorus* groups. This indicates potential susceptibility to a pathogen that would not affect sympatric congeners. However, no empirical evidence has become available to verify that a species-specific pathogen was responsible for gaps in the center of ABB's historical range (USFWS 2008, p. 31).

Further, there is a bacterium that has potential to affect ABB. *Wolbachia* are members of the Order Rickettsiales (α-Proteobacteria), a diverse group of symbionts with parasitic, mutualistic or commensal lifestyle (Negri and Pellecchia 2012, p. 356). *Wolbachia* are common intracellular bacteria that are found in arthropods and nematodes. These alphaproteobacteria endosymbionts (a major group of gram-negative bacteria) are transmitted vertically through host eggs and alter host biology in diverse ways, including the induction of reproductive manipulations, such as feminization, parthenogenesis, male killing and sperm–egg incompatibility. They can also move horizontally across species boundaries, resulting in a widespread and global distribution in diverse invertebrate hosts (Werren et al. 2008, entire). Evidence of *Wolbachia* infection has been found in five sympatric species of nicrophorine burying beetles, including the ABB. Studies have only begun to look at the effects to ABB and any population level effects of these infections is unclear and untested. Although there is limited existing evidence of disease/pathogens affecting populations, it could be a future risk for ABBs. Diseases that directly affect the ABB or affect carrion sources could affect future populations. Intentional or accidental introductions of non-native insects could introduce diseases/pathogens that ABBs have had no prior exposure or resistance.

3.8 CHANGING CLIMATE

3.8.1 Overview of Climate Change

Scientific measurements spanning several decades demonstrate that changes in climate are occurring and that the rate of change has been faster since the 1950s. Examples include warming of the global climate system and substantial changes in precipitation in some regions of the world, including increases in extreme drought and flood events. (For these and other examples, see IPCC 2014, pp. 7, 40-54). The main scientific measure of climate change, the earth's average annual temperature (the surface air temperature above land and oceans), shows clear evidence of the change since modern recordkeeping began in 1880 (Figure 3-1).

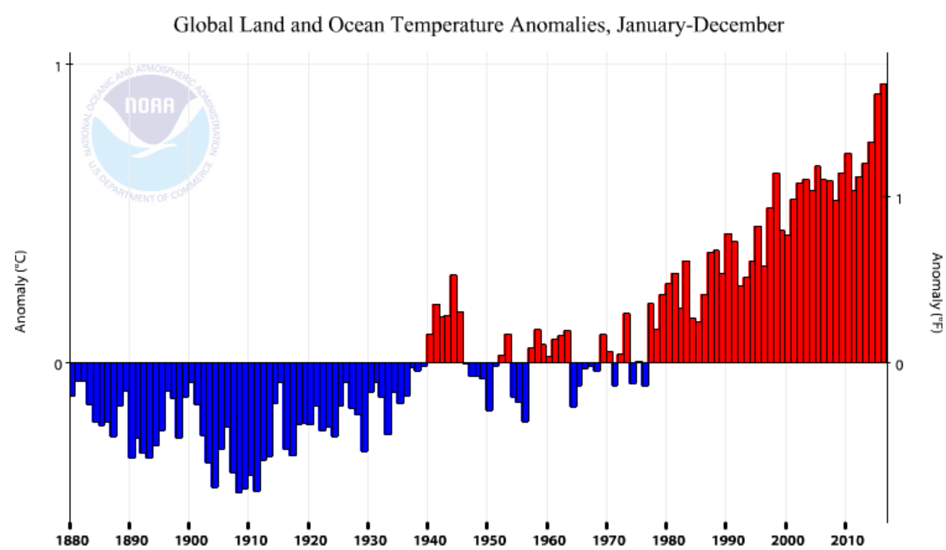


Figure 3-1. Change ("anomaly") in average annual global mean temperature (°C left axis, °F right axis), 1880 – 2016, relative to average for the 20th century. Source: NOAA https://www.ncdc.noaa.gov/cag/time-series/global

Two key points evident in Figure _are: (1) the average annual temperature varies, i.e., each year is not necessarily warmer than the last; and (w) despite the variability, a clear warming trend is evident. Building on extensive scientific data and analyses provided by the Intergovernmental Panel on Climate Change (IPCC) in its reports since the early 1990s, the most recent (2014) assessment by the IPCC concluded: "*Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen.*" (IPCC 2014, p. 2). A similar conclusion was stated in the Third National

Climate Assessment: "*Global climate is changing and this is apparent across a wide range of observations*." (Melillo *et al*., 2014, p. 18)

Results of scientific analyses presented by the IPCC show that most of the observed increase in global average temperature since the mid-20th century cannot be explained by natural variability in climate, and is "very likely" (defined by the IPCC as 90 percent or higher probability) due to the observed increase in greenhouse gas concentrations in the atmosphere as a result of human activities, particularly carbon dioxide emissions from use of fossil fuels (IPCC 2014, p. 40 and figures 1.1 and 1.10, pp.41, 49). Further confirmation of the role of greenhouse gasses comes from several scientific analyses. For example, Huber and Knutti (2011, p. 4), concluded it is extremely likely that approximately 75 percent of global warming since 1950 has been caused by human activities. Based on their evaluation of information available at the time, the Third National Climate Assessment includes a statement that "the majority of the warming at the global scale over the past 50 years can only be explained by the effects of human influences" (Walsh et al., 2014, p. 23 and associated citations). Various analyses in the IPCC's Fifth Assessment Report let to the conclusion that more than 50 percent of the observed global warming from 1951 – 2010 was "extremely likely" (defined as 95 – 100% likelihood) due to human-caused increase in GHGs concentrations and that it is "virtually certain" (99-100% probability) that internal variability (i.e., naturally occurring variations in climate) cannot account for the observed warming during that period (Bindoff *et al*., 2013, p. 869, 881-888, Fig. 10.5). At the sub-global scale, analyses by Hansen and Stone (2016, p. 532, 535-536) found that almost two-thirds of the continental scale impacts related to atmospheric and ocean temperature can be "confidently" attributed to climate forcing resulted from human actions.

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of greenhouse gas emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions (e.g., Meehl et al. 2007, entire; Ganguly et al. 2009, pp. 11555, 15558; Prinn et al. 2011, pp. 527, 529; Flato et al. 2013, entire). All combinations of models and emissions scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature (commonly known as global warming), over the near term (2016 – 2035), until about 2030– 2040 (Kirtman *et al*. 2013, pp. 955-956, 978-982,1009-1012 including Fig. 11.25). Although projections of the intensity and rate of warming begin to differ under different scenarios after about 2030, projections are very similar for all scenarios through 2050. The overall trajectory of all the projections is one of increased global warming through the end of this century, even for the projections based on scenarios that assume that the rate of greenhouse gas emissions will decline and their concentrations in the atmosphere will stabilize (RCP 4.5 and RCP 6.0) or decline (RCP 2.6) (Collins *et al*., 2013, pp. 1054-1058, including Tables 12.2 and 12.3).

Further, even if all greenhouse gas emissions ceased immediately, the global average temperature would likely continue to increase (one estimate being roughly another 0.5 °F), a situation that is known as "climate commitment". This is the result of response of the climate system to the level of greenhouse gases already in the atmosphere (Walsh et al. 2014, p. 25; Matthews and Zickfeld 2012, entire; Diffenbaugh 2013 entire; Frölicher et al 2014, entire).

Thus, there is very strong scientific support for projections that warming of the earth will continue through the 21st century and that the extent and rate of change will be influenced substantially by the extent of greenhouse gas emissions (IPCC 2014, pp. 58-62). (See IPCC 2014, p. 56, for a summary of other global projections of climate-related changes, such as frequency of heat waves and changes in precipitation. Also, see IPCC (2014, entire) for a summary of observations and projections of extreme climate events.

Within the Great Plains, average temperatures have increased and projections indicate this trend will continue over this century (Shafer et al., 2014, pp.442-445). Future precipitation is much more challenging to model and therefore projections of it have more uncertainty as compared to temperature. Precipitation within the southern portion of the Great Plains is expected to decline, with extreme events such as heat waves, sustained droughts, and heavy rainfall becoming more frequent (Shafer et al 2014, p. 445, Fig. 19.4; Walsh et al. 2014, pp. 28-40).

Seager et al. (2007, pp. 1181, 1183–1184) suggests that 'dust bowl' conditions of the 1930s could be the new climatology of the American Southwest, with future droughts being much more extreme than most droughts on record. More recently, Cook et al. (2015, entire) described the past history of repeated drought in the absence of changing climate, and projected a substantial increase in the risk of drought in the southwest and central plains under both moderate and high future emissions scenarios used for current climate change modeling (see below for an explanation of emissions scenarios), exceeding droughts observed during the last millennium. Other modeling also projects changes in precipitation in North American through the end of this century, including an increase in dry conditions throughout the central Great Plains (Swain and Hayhoe 2015, entire). Further, recent analysis involving the use of both moderate and high emissions scenarios shows that over this century, deep soil layers may become increasing dry during the spring, summer and fall snow-free/frost-free period (Schlaepfer et al. 2017, pp. 2-5, including Figures 3c for the US). See also Cook et al. 2016 (entire) for a comprehensive review of scientific papers on past and projected future "megadroughts" in North America.

Various changes in climate may have direct or indirect effects on species. These effects may be positive, neutral, or negative, and they may change over time, depending on the species and other relevant considerations, such as interactions of climate with other variables. Examples include: habitat fragmentation, alterations in key vegetation in response to temperature or other climate-related changes such as expansion of invasive species; or changes in types or abundance of competing species, predators, or prey. (e.g. see Settele et al. 2014, pp. 274–275, 278–19). Identifying likely effects often involves aspects of climate change vulnerability analysis. Vulnerability refers to the degree to which a species (or system) is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the type, intensity, and rate of climate change and variation to which a species is exposed, its sensitivity, and its adaptive capacity (Settele et al. 2014, p. 290; see also Glick et al. 2011, pp. 19–22). There is no single method for conducting such analyses that applies to all situations (Glick et al. 2011, p. 3; see also Foden et al. 2016, pp. 5-12). We use our expert judgment and appropriate analytical approaches to weigh relevant information, including uncertainty, in our consideration of various aspects of climate change.

The life history characteristics of many species are closely connected with climate conditions, e.g., thermal tolerances during certain stages of the life cycle. Accordingly, many climate scientists have expected that numerous species will shift their geographical distributions in response to warming of the climate (e.g., McLaughlin et al. 2002, p. 6070). In mountainous areas, species may shift their range altitudinally, in flatter areas, ranges may shift latitudinally (Peterson 2003, p. 647; Settele et al. 2014, pp. 294-301). A review of the scientific literature several years ago by Parmesan (2006, entire) led to a generalization that in face of changing climate (particularly increasing temperatures), many species are likely to move poleward or up in elevation to stay within the range of climate conditions associated with their life history. Evidence of poleward movement of the ranges of many species of plants and animals, consistent with changes in temperature, has been accumulating for many years (e.g., Parmesan et al. 1999; Root 2003; Hickling et al. 2006; LaSorte and Thompson 2007; Dunn and Winkler 2010; Chen et al. 2011; Dunn and Møller 2013). A recent meta-analysis of long-term datasets revealed that relatively substantial shifts in the distribution of some species have already occurred, resulting in range contractions for some species and expansions for others (Parmesan and Hanley 2015, p. 851). Nevertheless, the extent to which range shifts can or will occur for many taxa remains an open question (e.g. Early and Sax. 2011, entire), and some studies have identified movements that are not well-linked to changes in climate (e.g., La Sorte & Jetz, 2012; Zhu *et al*. 2012; Comte & Grenouillet 2015), and some species have not shown range shifts.

Another challenge relates to the non-stationarity of changes in temperature or other conditions under changing climate, i.e., changes are continuing, not stabilizing. This means temperature or other climate conditions important to a species may remain within a suitable range of values for a period of time but become unsuitable over time, prompting another “adapt, move, or die” situation for species that cannot tolerate the change.

The ability to move varies by species. For example among animals this can vary from birds which can move relatively easily and rapidly via flight, to ground-dwelling invertebrates that are only capable of short distance movements at any given time and for which range shifts may take a considerable amount of time and could span several generations. Range shifts may result in localized extinctions over parts of the range, while the occupied range may expand elsewhere, depending upon habitat suitability and other variables (e.g., presence of competing species). Changes in geographical distributions can vary from subtle to more dramatic rearrangements of occupied areas (Peterson 2003, p. 650). Peterson (2003, p. 651) expected that species occupying flatland areas such as the Great Plains generally would undergo more severe range alterations than those in montane areas. Additionally, populations occurring in fragmented habitats can be more vulnerable to effects of climate change and other threats, particularly for species with limited dispersal abilities (McLaughlin et al. 2002, p. 6074). Species inhabiting relatively flat lands will require corridors that allow movements, presuming suitable habitat exists in other areas.

Where existing occupied range is bounded by areas of unsuitable habitat, the species' ability to move into suitable areas is reduced and the amount of occupied habitat could shrink accordingly. In some cases, particularly when natural movement has a high probability of failure, management involving translocation area within known current or historical range may be a way facilitate a shift to habitat that is likely to remain suitable for a longer period of time under changing climate. This can add to the resilience of a species (or population) to withstand changing climate, and/or it may "buy time" pending development of other measures and/or emergence of new information. For example, the Service has conducted climate-related translocation of the endangered Key tree cactus (*Pilosocereus robinii*) to establish individuals at locations in the Florida Keys within their historic range that are less susceptible to effects increased soil salinity in the habitat of this species due to ongoing and projected sea level rise and related storm surge. This effort to "buy time" for about two decades as part of the recovery effort for the species, which also includes *ex situ* management of individuals at a botanical garden, and on-going studies of the adaptive capacity of the species to withstand more saline soils. In situations involving species that cannot or are considered highly unlikely to be able to tolerate changing conditions, and which have very limited capacity to move or face barriers to moving (e.g, topographic features, habitat fragmentation) one management option that may be considered is translocation to establish one or more populations in locations outside the historic range of a species. This type of translocation is referred to by various terms such as "managed relocation", "assisted colonization", and "assisted migration"), and although it may be considered in an attempt to ensure persistence of a population or species, there is no guarantee of success and there are numerous complexities and controversies associated with such endeavors (e.g., Schwartz et al. 2012, entire).

The exposure of species to changes in temperature and their thermal tolerance is one of the main considerations involved in assessing the vulnerability of species to changing climate (Glick et al. 2011, entire). Species differ in the range of temperatures they can tolerate without experiencing effects on reproduction or survival of individuals. Generally speaking, when a species is exposed to temperatures above or below the range to which they are adapted, the magnitude of the change and how long it persists can impact survival and/or reproductive success of individual, which in turn results in effects on populations. Characterizing this in a general sense, several outcomes are possible:

1. At the extreme, the temperature change can reach a level that individuals cannot tolerate, i.e., a lethal threshold. Under such conditions, populations are extirpated.

2. Another possibility is the temperature reaches a level at which the individuals exposed to it can survive, but cannot successfully reproduce. Over time this leads to reduction in population abundance and distribution, and eventually results in extirpation of the population once the adults die. In this type of situation, although individuals will still be detected during surveys or monitoring this situation is actually one of "quasi-extinction", i.e., the population is still extant but it is a simply a matter of time before it no longer exists. The period of time could range from decades for species with long lifespans, to a few years for species that live only a year or less.

3. Yet another possibility is that individuals are able to survive but their reproductive success declines. Over time this results in reduced abundance; the eventual outcome depends on whether some level of stabilization occurs such that reproductive success balances mortality and the population continues to persist but at a lower level of abundance, which could reduce its resilience. Changes in distribution also are possible with lower abundance.

Another important general consideration is the adaptive capacity of a species to changes in its environment. In the context of changing climate conditions (e.g., temperature, moisture) to which plant and animal species are exposed, adaptive capacity refers to the ability of a species or population to cope with changes and it is one of the three main components of assessing the vulnerability of species to changing climate (Glick et al. 2011, pp.19-22; Foden et al. 2016, pp. 5-8). The adaptive capacity of species is considered to have three main components (Beever et al. 2016, p. 132, and citations therein): (1) evolutionary adaptive capacity (i.e., the ability to evolve, via genetic changes); (2) dispersal ability, which may involve highly localized to long-distance movements to locations where conditions are within the range of what the species can tolerate; and (3) and phenotypic plasticity, a term that generally refers to behavior adjustments. In general, the stress on a species that results from exposure to temperatures outside what it normally tolerate is expected to increase with the frequency, magnitude, and duration of the exposure (e.g., Buckley and Huey 2016, entire).

Ideally, populations will adapt to conditions that otherwise would have been lethal and a cause of extinction, a situation referred to as "evolutionary rescue" (Bell 2013, p. 2). Although it is clear that the adaptive capacity of a species is an important consideration, it is challenging to assess when the tolerances of a species, their adaptive capacity, or both, are poorly understood – as often is the case. Although considerable effort is being made in the scientific community to better understand both tolerances and adaptive capacity in the context of a changing climate, these same studies illustrate widespread agreement about the need for much more research to better understand both topics (e.g., Buckley and Huey 2016, entire; Bell 2013, entire; Chevin and Lande 2010, entire; Hoffman and Sgrò 2011, entire; Nicotra et al 2015, entire; Sgrò et al. 2016, entire; Telemeco et al. 2016, entire; Terblanche et al. 2011).

A related general consideration with regard to temperature tolerance is whether a species is an "endotherm" or an "exotherm." Endotherms can make internal adjustment to maintain their body temperature within a suitable range. Mammals and birds are examples of endotherms. In contrast, an exotherm is a species that has very limited or no such ability, and their internal body temperature is depends mainly on the temperature in their environment. Examples of exotherms include reptiles (e.g., snakes, lizards) and insects, including the American burying beetle.

Tolerances to changing conditions other than temperature are important for many plants and animal species. Changes in soil moisture are an example. Soil moisture is influenced by many factors, such as the type of soil, the timing and magnitude of precipitation (e.g., snow, rain), the frequency and length of drought, and temperature. As noted above, drought is projected to be more frequent and extended in many parts of the world, including the Great Plains, with associated effects that include reductions in soil moisture. Further, the combination of increasing temperature and drought, referred to as "hot drought" results in greater impacts on various ecological conditions (e.g., water availability, soil moisture) than increased in temperature or drought alone (Overpeck 2012, entire; Luo et al 2017, entire)

In addition to uncertainty about the extent to which species have the adaptive capacity to cope with the effects of changing climate (which can vary by species, populations, and differences in local conditions), another underlying question across many of the topics described above involves the extent to which any of the possible adjustments to increasing temperature or other aspects of changing climate can occur rapidly enough avoid population extirpation or species extinction, given the velocity of climate change (e.g., Dobrowski et al. 2013, entire; Loarie et al., 2009, entire; Ohlemüller 2011, entire; Sahlean et al. 2014, entire). One key aspect of this involves how rapidly species are able to change their "climatic niche", which refers to the set of temperature and precipitation conditions where a species or population occurs and has been able to persist in the past, and which is influenced by tolerances for temperature and other non-biotic conditions and by interactions among species (Jezkova and Wiens 2016, and citations therein). A recent study found that across 266 phylogenetic groups analyzed, the rates of niche change varied for individual taxa, but overall were much slower than the rates of projected climate change, "suggesting that the amount of change needed to persist may often be too great, even if these niche shifts were instantaneous" (Jezkova and Wiens 2016, p. 1).

3.8.2 – Effects to the Species

The taxonomy and life history of ABBs indicate a limited ability to tolerate warmer temperatures. Nicrophorus abundance and diversity are higher in cooler climates. There are 15 Nicrophorus species in the United States and Canada, but only 2 endemic to Central America and they occur at higher elevations. Reasons for burying beetles' lack of success in warmer climates include increased competition with flies and ants, as well as increased rates of carcass decomposition. Carcass decomposition is dominated by dipteran species (true flies) and the diversity of dipteran species using carcasses increases in warmer climates. Based on species distributions and existing climate conditions, few Nicrophorus species appear to be capable of maintaining populations in areas with average summer mean-maximum temperatures at or exceeding the 95 ° F threshold (N. *carolinus,* and possibly *pustulatus* and *marginatus*) and there are no Nicrophorus species in areas with average summer mean maximum temperatures exceeding 100 ° F. Under the RCP 8.5 emissions scenario (approximately current rate of climate change) all Southern Plains ABB populations would be projected to have summer mean maximum temperatures of 98-100° F by 2040-2070 and 102-104° F by 2070-2099. All Nicrophorus species are at risk of extirpation within the Southern Plains ABB range under these projected climate conditions.

Climate has always limited the ABB range to some degree. Populations at the northern edge of the historic range were limited by cool night time temperatures and shorter growing seasons (see temperature requirements in section 2.4.1) and could potentially expand to the north as climates warm. However, there are no current populations near the northern edges of the historic range and habitat limitations may prevent existing populations from moving north. The southern edge of the ABB range is likely limited by high temperatures (Figure 3-2). The western edge of the species range has been limited by reduced precipitation and soil moisture. Although temperature and other effects of climate change are expected to affect ABBs in both the northern and the southern parts of the range, we expect the populations in southern areas to be affected sooner and to a greater extent. ABBs near the southern and western edge of the range may already be at their limits for climate related tolerances and have a limited ability to adapt to rapidly changing climate conditions. Mean maximum temperatures for summer months are projected to increase by 6 or more degrees by the end of the century in southern analysis areas and approach or exceed 100°F (see information in section 5.4).

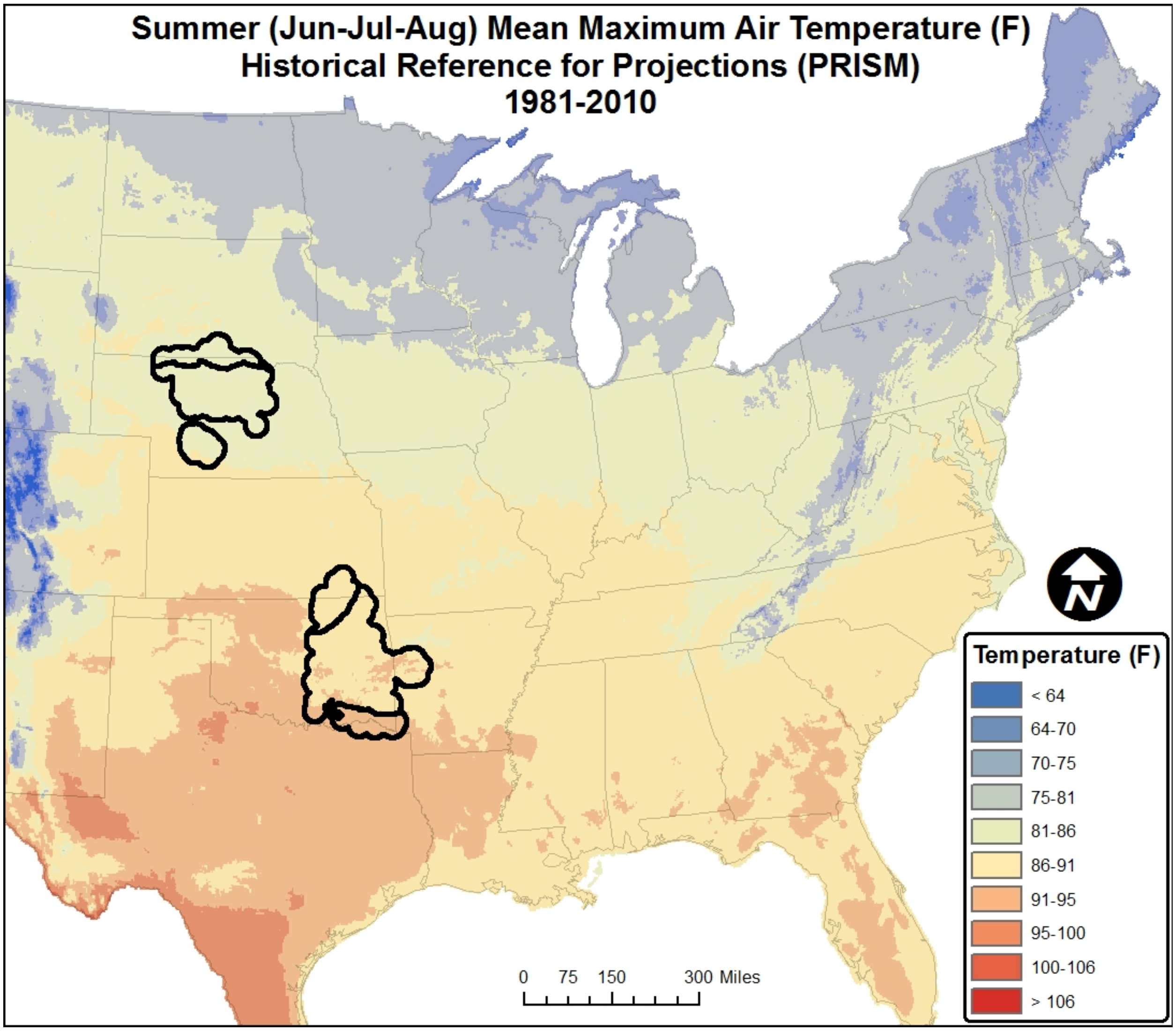


Figure 3-2. Mean maximum summer maximum air temperature (F) from 1981-2010. Data Source PRISM.

Increased air temperatures, changes in precipitation, increased evaporative losses, and prolonged droughts may stress or kill individual ABBs and reduce reproductive success or reduce the time periods with suitable conditions for reproduction. Temperature tolerances for ABBs are currently unknown, but high air temperatures have been documented to kill or sterilize ABBs at captive colonies when air conditioning systems have failed, resulting in colony temperatures at 85-90°F for about two weeks (Bob Merz Personal Comm. October 6, 2016). Survey protocols require traps to be checked in the morning because ABB mortalities have occurred when they are confined in traps during warm days. More indirect effects of increased temperatures and reduced precipitation or soil moisture may be related to competition. Congeners with higher temperature and or lower moisture tolerances, like *N. carolinus*, may be more competitive and reduce or eliminate ABBs in southern populations (Abbott and Abbott 2013, p. 2).

“Insects are adapted to particular temperature ranges and temperature is often the most detrimental environmental factor influencing their populations and distribution. In general, within optimum ranges of development and as environmental temperature decreases, their rates of development slow and cease at the lowest (base) temperature, while as temperature rises, development rates increase up to an optimum temperature, above which they again decrease and eventually cease at their temperature maximum.” (Damos and Savolpoulou-Soultani 2012). Increasing temperatures resulting from climate change could reduce the reproductive success of ABBs by reducing the portion of the active season with suitable temperatures for reproduction. Curtis Creighton (personal comm. July 2016) provided information from recent temperature studies with *N. orbicollis* that indicates even small increases in temperature can affect reproduction. The percent of successful broods declined at temperatures greater than 20° C (68° F) and declined rapidly at any temperatures greater than 25° C (77° F). An increase of only 2-3 degrees (from 25° to 27-28° C) stopped most beetles from attempting to prepare a carcass for reproduction and those that did were not successful. *N. orbicollis* in the northern portion of their range (Wisconsin) can actually have a longer period of suitable climate conditions for reproduction than *N. orbicollis* in the southern portion (Oklahoma) due to these temperature restrictions. This type of research has not been conducted with ABBs, but *N. orbicollis* is the most similar congener and has a similar range.

Increased air temperatures can also affect reproductive success by reducing the availability of suitable carrion. ABBs are only active at night and this combination of factors creates a very narrow window of time for otherwise suitable carcasses to be available for ABBs to find, bury and prepare for reproduction. Higher temperatures cause carrion to decompose more rapidly and fly larvae to quickly consume small carcasses under these conditions. At high temperatures, exposed carcasses can be heavily infested with fly larvae within two days and carcasses may only be suitable and available for 1-2 nights.

Adult ABBs use secretions to slow decomposition, but high temperatures could reduce the effectiveness of the secretions or accelerate decomposition to a degree that the secretions are overwhelmed (Jacques et al. 2009. p. 871). While the ABB has life history requirements similar to other carrion beetles, it is the largest *Nicrophorus* in North America and requires a larger carcass to reach its maximum reproductive potential (i.e., to raise a maximum number of offspring) than the other burying beetles (USFWS 1991, p. 2; Kozol et al. 1988, p 37; Trumbo 1992, pp. 294-295). ABBs also have a longer time period for egg and larval development than other carrion beetles, so the carcass must last longer (at least 12-14 days) to provide food and moisture for larvae. Temperature related increases in decomposition and development of fly larvae could limit or prohibit reproductive success for ABBs.

Evidence from previous research also supports temperature related impacts to Nicrophorus reproduction. Trumbo (1990) found the Sandhills habitat in North Carolina was not conducive to burying beetle reproduction in late summer. The open canopy forest might increase surface temperature and speed decomposition, favoring exploitative competitors such as carrion flies and ants which tend to be the first to arrive on carcasses placed in the field during daylight. Trumbo concluded that burying beetles did not attempt to reproduce in this locale in late summer. One aim of this study was to examine phenology and reproductive success of burying beetles in southeastern woodlands of North America and to compare these findings with previous studies in northern habitats, especially with those of Wilson and Fudge (1984). On both days 1 and 2, burying beetles discovered and buried a greater proportion of available carcasses in Michigan than in North Carolina. Beetles in Michigan also produced more successful broods after they located and buried a carcass. This measure of success is not directly comparable among studies since Wilson and Fudge (1984) collected data over an entire breeding season while Trumbo's study only measured brood success on carcasses discovered in July and August. Nevertheless, Wilson and Fudge (1984) did not indicate extreme fluctuations in reproductive success, so at least in midsummer, burying beetles in the southeast experience more reproductive failures. Beetles might have more difficulty in North Carolina because the later average time of discovery and warmer temperatures lead to more advanced decomposition of the carcass before nest-building is completed and oviposition by beetles begins (Trumbo 1990).

If ABBs have similar temperature tolerances (relative to *N. orbicollis*, described above) for reproduction, then ABBs in Southern Plains analysis areas could have a very limited time period for reproduction relative to Northern Plains analysis areas. According to Oklahoma Mesonet data, average soil temperatures in the 4-10 inch range reach 77°F by early to mid-June and retain those temperatures until mid to late October in Southern Plains analysis areas. All Mesonet sites are relatively open and may have tall grass, but do not have shade from trees. Soils in shaded areas may be somewhat cooler. In the spring, southern soil temperatures at 4-10 inches reach 55°F by mid to late March and night time temps reach 55-60 by late April in many years, so reproduction for ABBs could be limited to parts of April through May or early June. Any tenerals emerging in June may have to survive until fall (possibly active through October) and would not have time to reproduce that summer before soil temperatures became too warm. Then ABBs would over-winter until April before they could reproduce themselves. This requires a very long period of activity, a relatively short inactive season and then reproduction nearly a year after they emerge. The long period of activity could result in higher mortality, injuries, aging, and over wintering stress on adult ABBs before they can reproduce. Climate changes with warming temperatures and shorter winters could exaggerate these effects and shorten the effective reproductive period for ABBs in the Southern Plains analysis areas.

ABBs in Northern Plains analysis areas may have a longer time period for potential reproduction than ABBs in Southern Plains analysis areas. ABBs in the north would emerge from over wintering by late May or June and be ready to reproduce at that time. June –August could have suitable conditions for reproduction in northern areas and that could be nearly twice as long as the Southern Plains analysis areas. ABB tenerals in northern areas emerge later than in those in the south (usually July or August) and are only active for a few months before becoming inactive by September or October for the winter. This could reduce the mortalities and stresses of survival during the active season and allow higher survival of tenerals going into the winter and surviving into the next active season.

Climate change also has potential to affect habitat availability through changes in land uses. Increased temperatures could increase water demands and usage for irrigation and potentially lower groundwater levels in aquifers. Lower water tables could affect soil moisture in the Sandhills and other areas with groundwater near the surface. Also, increased temperatures and longer droughts may increase the percentage of pastures that are heavily grazed or increase the demand for hay and encourage more cuttings. With reduced plant growth during droughts, recovery from grazing or mowing down to short heights is slow. Both of these conditions would decrease the availability of suitable habitat because more pasture and hay lands would be maintained as unsuitable habitat (short grass <8 inches) for longer periods of time in Southern Plains analysis areas.

3.9 OTHER POTENTIAL RISKS

3.9.1 Pesticides

For any man-made toxin, to be a significant factor in the decline of ABB populations, we would have to account for the lack of equivalent impact on the sympatric congeners of the ABB. Unfortunately, there is limited historical information (e.g., Trumbo and Thomas (1998, entire) regarding *Nicrophorus* community structure with which to assess effects of past DDT spraying or other contaminants. It is possible that some ABB, and presumably other *Nicrophorus*, populations may have been extirpated by pesticide use, but there is no existing information to indicate that pesticide use has caused declines or extirpations over large areas of the ABB range (Sikes and Raithel 2002, p. 105).

Most of the existing ABB range does not experience any widespread pesticide applications. Most of the known occupied habitat on the western portions of the ABB range is grassland or woodland/grassland mix that has grazing or hay production as an agricultural use and pesticides are not routinely or widely used (such as aerial or broadcast spraying) in these types of agriculture. Pesticides are frequently used for row crops that may be within the ABB range, but ABBs are rarely found in row crops. Pesticide applications for grasshoppers has been proposed in past years for grassland portions of the ABB range in NE and SD, but has rarely been implemented on a large scale. In NE and SD, a large portion of the known ABB distribution overlaps with distributions of economically damaging grasshoppers that are managed using Dimilin and Malathion pesticides. Dimilin was found to have some negative effects on *N.*

orbicollis brood success when carcasses were exposed to the pesticide and then later used for larval development. Malathion caused direct mortality of *N. marginatus* Fabricius, a diurnal species, when sprayed directly, but would be unlikely to directly harm nocturnal ABBs. Indirectly, Malathion on a carcass might stress parental beetles and cause changes in brood size (Jurzenski 2012, pp. 112–115). These pesticides have potential adverse effects for ABBs, but the potential effects vary with the pesticide and application method, scale and timing.

Herbicides are more likely to be used in portions of the current range, but are less likely to directly affect ABBs. ABBs are below ground most of the time and would have limited exposure to most herbicides. Herbicides are used to some degree in portions of the ABB range to control broad-leave weeds (forbs) and reduce competition for grasses in pastures. Herbicides that reduce forbs in rangeland could reduce habitat diversity and food sources for potential carrion sources. This could indirectly reduce habitat suitability for reproduction and feeding for ABBs.

3.9.2 Artificial Lighting

Circumstantial support for artificial lights as a factor in the decline could be derived from the fact that most extant populations of ABB occur in relatively remote, lightless areas, and artificial lighting was becoming widespread during the late 1800s (Bright 1949, entire), concurrent with the beginning of *N. americanus*' disappearance from the Northeast. However, fluorescent lights (including blacklights like those used in "Bug Zappers") are considerably more attractive to night-flying insects, and these are a relatively recent feature of the landscape (Sikes and Raithel 2002, p. 106). Additionally, it is difficult to separate the effects of lights and the related land use changes and fragmentation that usually coincide with the lights. Both *N. orbicollis* and *Necrodes surinamensis*, and other light-attracted silphids, remain abundant in some areas with lights. It remains at least possible that artificial lights, if they are responsible for a chronic, albeit low, level of adult attrition, could be affecting ABB populations. Nevertheless, it presently seems that if artificial lighting has had a negative effect on ABB it has been minor relative to other influences (Sikes and Raithel 2002, p. 106).

3.10 SUMMARY OF RISK FACTORS

This chapter is an overview of the potential risk factors (Table 3-1) and additional discussions of for each analysis area are covered in Chapters 4 (Current Conditions) and 5 (Future Conditions and Viability). The American Burying Beetle Recovery Plan (USFWS 1991) and the 5-year Status Review of the species (2008a) identify the following factors as potential threats to ABB: direct habitat loss and alteration, increase in competition for prey, inter and intra-specific competition, increase in edge habitat, decrease in abundance of prey, loss of genetic diversity in isolated populations, disease/pathogens, DDT, agricultural and grazing practices, and invasive species. None of these theories alone adequately explain why the ABB declined over much of their historic range while congeneric species are still relatively common range wide [there are eight sympatric congeners which are not in peril (Sikes and Raithel 2002, p. 104)] and some of these risks are not relevant in all remaining areas. Much of the evidence suggesting the reduction of appropriate carrion resources as a primary mechanism of decline is circumstantial, but this hypothesis fits the temporal and geographical pattern of the disappearance of ABBs, and is sufficient to explain why ABBs declined while related species did not. It also may explain current distributions and the presence or absence of ABBs in most of the existing analysis areas. Potential risk factors are not equal in all portions of the ABB range and some risk factors have changed since the recovery plan was written. Some remaining populations have risks associated with areas of urban development, but most current ABB populations are in rural areas and have potential risks associated with agricultural land uses. Risks associated with the effects of changing climate, including increasing temperatures, are now a significant threat for some analysis areas.

CHAPTER 4: CURRENT CONDITIONS

4.1 CURRENT AND HISTORICAL RANGE

Historically, the known geographic range of the ABB included 35 states in the United States and the southern borders of three eastern Canadian provinces, covering most of temperate eastern North America (Chapter 2 - Figure 2.2; Anderson and Peck 1985, p 54; USFWS 1991, p. 5; Peck and Kaulbars 1987, p. 75). During the 20th century, the ABB disappeared from over 90 percent of its historical range (Ratcliffe 1995, p. 1) (Figure 4-1). The last ABB specimens along the mainland of the Atlantic seaboard, from New England to Florida, were collected in the 1940s (USFWS 1991, p. 6, Table 1, p. 7). At the time of listing in 1989, known populations were limited to one on Block Island, Rhode Island; and one in Latimer County, Oklahoma.

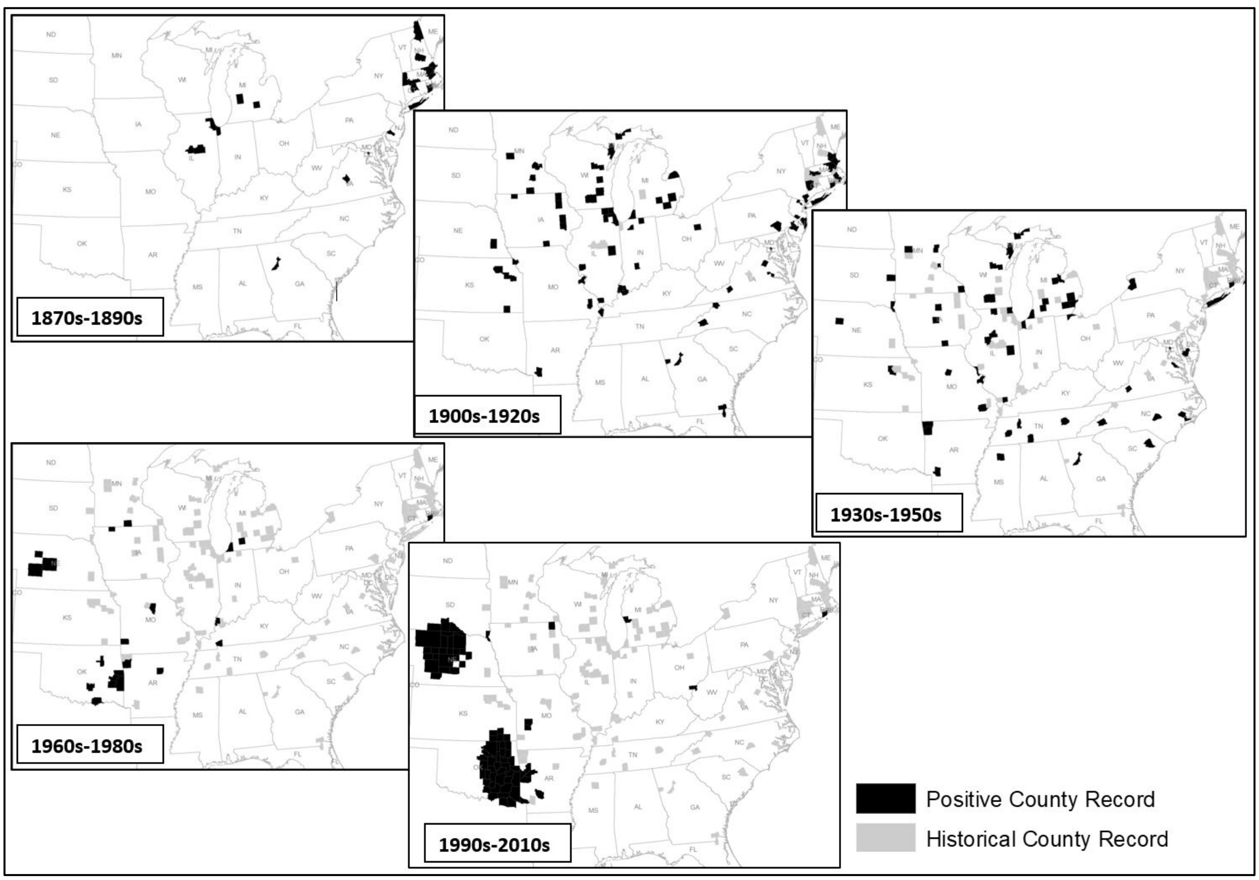


Figure 4-1. County records of American burying beetle by 20 year periods. Black counties represent records with that 20 year period. Gray counties represent records older than 40 years.

After the species was listed, survey efforts increased and the ABB was discovered in more locations, particularly in South Dakota, Nebraska and Oklahoma (Amaral *et al.* 1997, p. 125). Surveys resulting in the collection of other *Nicrophorus* species, which use similar trapping techniques as those used for ABBs, have continued throughout the eastern United States without collection of the ABB; Amaral et al. (1997) identifed surveys from several other states, including Maine, Massachusetts, Michigan, mainland Rhode Island, Long Island New York, New Jersey, North Carolina, Ohio, Louisiana, Tennessee, Florida and Pennsylvania; however, no additional remnant populations were discovered (Amaral et al. 1997, p. 125). Additionally, ongoing research efforts at universities and others entities across the ABB's historical range have potential for by-catch of ABB when studying other animals, particularly insects. For example, researchers studying prairie mole cricket (*Gryllotalpa major*), recorded the first ABB captured at the the Tallgrass Prairie Preserve in Osage County, Oklahoma. Consequently, the Service sent letters to all states across the ABB's historical range, inquiring if any by-catch of ABB had been recorded; we did not receive any positive responses. We also reviewed museum records and reached out to curators for any and all ABB records and included any new records in our analyses.

Currently, the ABB is known to occur in nine states: on the East Coast, it is found on Block Island off the coast of Rhode Island, and a reintroduced population now occurs on Nantucket Island off the coast of Massachusetts (Figure 4-2). It is also found in eastern Oklahoma, western Arkansas (Carlton and Rothwein 1998, entire), Loess Canyons in south-central Nebraska and Sandhills in north-central Nebraska (Ratcliffe 1996, 60–65; Bedick et al. 1999, entire), south-central South Dakota (Backlund and Marrone 1997, entire; Ratcliffe 1996, 60–65), Chautauqua Hills region of southeastern Kansas (Miller and McDonald, entire), northeast Texas (Godwin 2003, entire), and a newly reintroduced colony in Missouri is showing success (personal communication with Bob Mertz, St. Louis Zoo, May 30, 2013). The ABB population in Missouri is a nonessential experimental population (under section 10(j) of the ESA) that was reintroduced to the area in 2012. A reintroduction effort in Ohio is ongoing, but no overwinter survival of the introduced ABBs has been documented and no viable or self-sustaining populations are known in that state. A potential report of an ABB in Michigan in 2017 is being investigated and surveys in 2018 failed to confirm the report of ABBs. Additional surveys are planned in 2019 and we do not have enough information on the Michigan report to confirm or assess the status of ABBs in these areas.

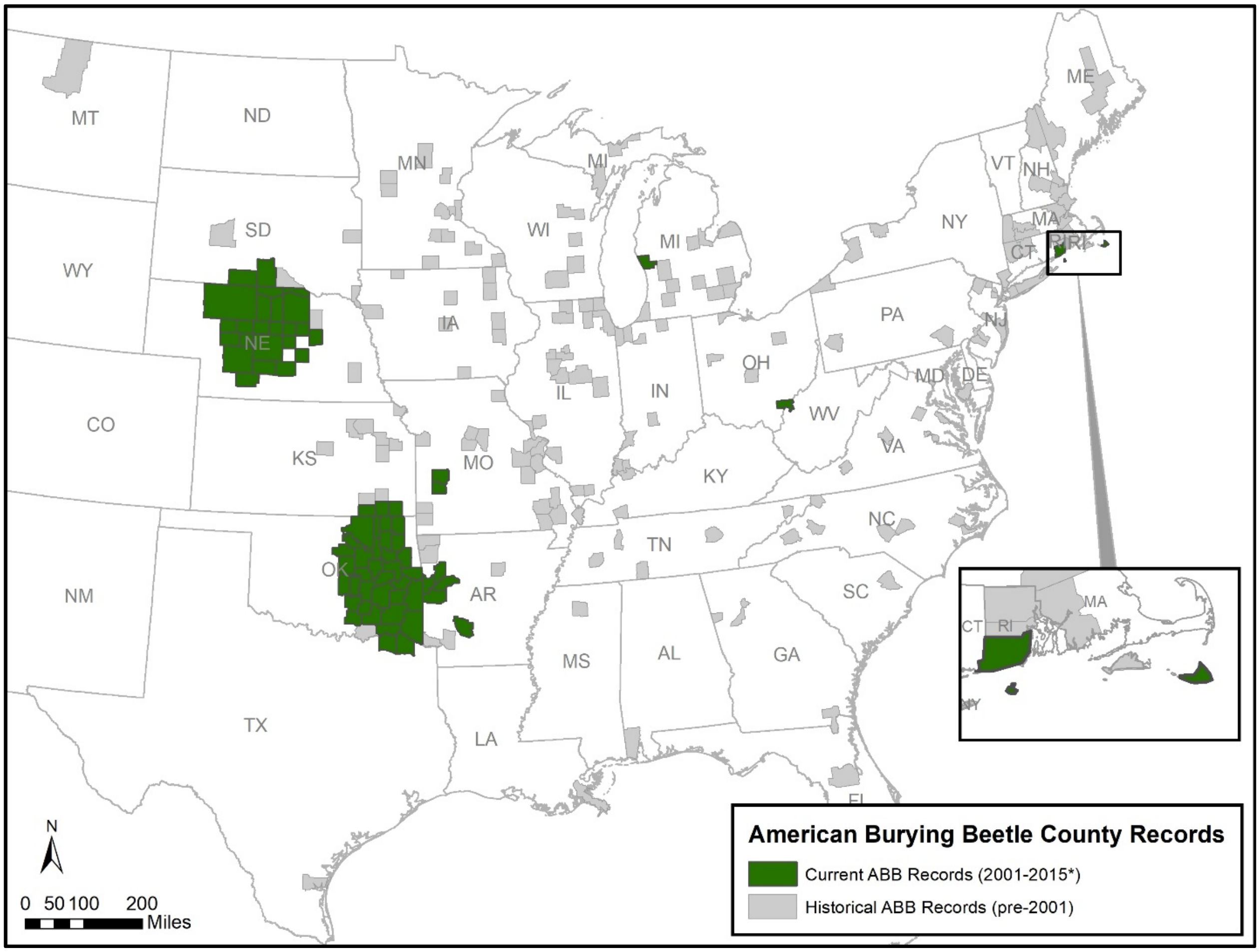


Figure 4-2. Current and historical county records of the American burying beetle from 1870 to 2015 (*except for 2017 Michigan occurrence).

4.2 HABITAT AVAILABILITY

The ABB is considered a generalist in terms of the vegetation types where it is found, as it has been successfully live-trapped in a wide range of habitats, including wet meadows, partially forested loess canyons, oak-hickory forests, shrub land and grasslands, lightly grazed pasture, riparian zones, coniferous forest, and deciduous forests with open understory (Walker 1957, entire; USFWS 1991, pp.14-17, 2008, pp.8-11; Creighton et al. 1993, entire; Kozol 1995, p. 8; Lomolino et al. 1995, entire; Lomolino & Creighton 1996, entire; Jurzenski 2012, pp.47-72; Willemssens 2015, pp.5-6). See Chapter 2, Section 2.4.4 for further description of the ABB's habitat.

Potential habitat for the ABB within the current range was evaluated by using LANDFIRE/GAP land cover map unit descriptions (Appendix A). Land cover types were mapped within the current range and reviewed for potential suitability for ABB use. Approximately 2,040 land cover types were identified within the current range and grouped by favorable, conditional, marginal, and unsuitable ABB habitat classifications, which we defined as follows:

Favorable - Land cover types with suitable soils and vegetation to support all or critical portions of the ABB life cycle. Favorable lands may range from high to low quality ABB habitat, but most of these lands should be capable of supporting ABB populations. The ABB uses a wide variety of habitats and favorable land cover types including multiple forest, savanna, shrub, and grassland/herbaceous land covers.

Conditional - Land cover types that can be favorable under some conditions and unsuitable under others. For example, most pasture land in southern plains analysis areas may be favorable habitat if grazing is light to moderate or infrequently mowed, but the same area may be unsuitable if it is heavily grazed or frequently mowed. Fields managed for hay can be unsuitable habitat when the vegetation is mowed at short heights, but can be favorable habitat between cuttings when the grass/hay is tall enough to provide suitable habitat for birds and mammals that are carrion sources for ABBs. Wetlands are another example. They may be unsuitable under flood conditions, but very important habitat during droughts, given that ABBs need moist soils.

Marginal – Land cover types that can provide limited habitat for some portions of the ABB life cycle. Examples include land covers that have poor or thin soils (such as barren lands) that make them unsuitable for reproduction, but may provide habitat for day use or help support potential carrion species to some degree.

Unsuitable – Land cover types that do not provide habitat that would be favorable for any portion of the ABB life cycle (such as open water or highly developed urban lands).

These classifications were mapped and quantified (in acres) for each analysis area, which are described in Chapter 2, Section 2.5.2. In general, land cover types were reviewed for vegetation and soils that could directly or indirectly support ABB life history needs for food, shelter and reproduction. This includes land cover types that provide at least seasonal habitat for ABBs.

As a caution, the detail and accuracy of the land cover data is limited and the actual habitat quality or suitability may not be accurately reflected for all areas with this analysis of available habitat. The existing information for ABB habitat suitability is also limited and the land cover classifications for suitability were conservative. Land covers were assumed to be favorable if some level of ABB use was documented and no obvious habitat limitations were included in the land cover descriptions. Most of the U.S. Forest Service lands in Oklahoma and Arkansas are considered favorable, but the limited surveys in those areas indicate that ABBs may not be present or are present in low numbers. Readers should not assume that all areas of favorable or conditional lands support ABBs.

Table 4.1 Total area (acres) of American burying beetle habitat classifications by analysis area.

Analysis Area	Analysis Area	Favorable habitat	Conditional habitat	Marginal habitat	Unsuitable habitat
Red River	3,251,894	1,268,571	1,201,914	207,922	573,488
Arkansas River	17,753,431	8,134,009	5,800,174	536,420	3,282,828
Flint Hills	3,706,908	674,001	2,144,209	27,870	860,829
Loess Canyons	2,758,610	815,215	849,606	22,126	1,071,662
Sandhills	10,819,170	1,069,818	7,537,587	26,279	2,185,485
Niobrara River	4,108,712	261,376	2,684,056	16,037	1,147,244
New England	42,431	13,081	9,459	3,325	16,566

4.2.1 Red River

The Red River Analysis Area includes 3,251,894 total acres with 2,678,406 acres of potential habitat (combined favorable, conditional and marginal land cover types, see Table 4-1) in portions of Arkansas, Texas and Southeastern Oklahoma near the Red River (Figure 4-3).

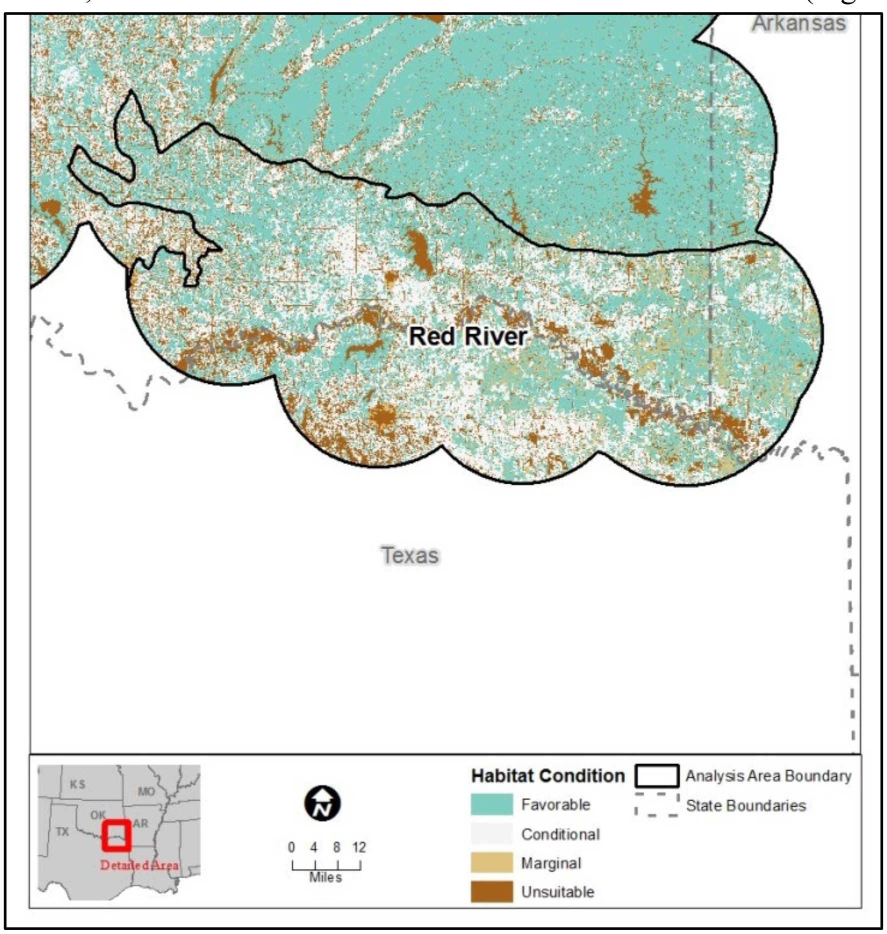


Figure 4-3. American burying beetle habitat condition in the Red River Analysis Area

Of the total analysis area, favorable habitat comprises 39%, conditional habitat 37%, and marginal habitat 6%, while the remaining 18% is considered unsuitable. The flood plain of the Red River and areas with more level topography and suitable soils support relatively large areas of agricultural row crop, hay, or pasture lands with more intensive agricultural use that are less favorable for ABBs. Bottomland hardwood forests, mixed hardwood and evergreen forest and commercial timber (mostly pine plantations) operations dominate large areas (1,109,107 acres or 34%) of the analysis area. Most forested habitat is considered favorable for ABBs, although intensively managed pine plantations and forested areas in the mountain ranges of Oklahoma and Arkansas tend to be marginal due to plantation management practices and thin rocky soils in the old mountain ranges.

Large portions of this analysis area are dominated by grassland/pasture lands with some percentage of trees and shrub cover (1,787,980 acres or 55%). Most of these grassland/pasture lands are considered conditional habitat and support agricultural uses like grazing and hay production that can affect habitat suitability. The large percentage of conditional habitat makes the ABB population in this analysis area more sensitive to changes in land uses that affect the habitat suitability. For example, pastures and hay fields are more intensely grazed or mowed during drought periods when demand for grass/hay is high and keeps the habitat in an unsuitable or marginal condition for longer time periods. Discussions of potential impacts of land uses (including agriculture and forestry practices) on ABB habitat are included in Chapter 3.

Land use from agriculture and silviculture (pine plantations) practices make much of this area marginal for ABB use. There are no large urban areas, but multiple small to medium communities and some development due to tourism and retirement/seasonal homes, have some areas dominated by low to high intensity residential development. Developed areas are about 3% of the total analysis area.

Current risk factors include habitat loss and alteration due to intensive agricultural land uses, commercial forestry, and some areas of urban development (see related discussions in Chapter 3). Climate change, as discussed in Chapter 3 and 5, may also be affecting the suitability of ABB habitat in this analysis area. Portions of this analysis area are at the southern and western edge of the known ABB range and thresholds for temperature and moisture limits could be exceeded with potential climate changes in future years. ABBs have declined or been extirpated from large portions of this analysis area in the last 10 years (see section 4.4.1) and this may reflect reductions in suitable habitat due to recent drought and high summer temperatures.

4.2.2 Arkansas River

The Arkansas River Analysis Area includes 17,753,431 total acres with 14,470,603 acres of potential habitat (combined favorable, conditional and marginal land cover types, see Table 4-1) in portions of Arkansas and Oklahoma (Figure 4-4).

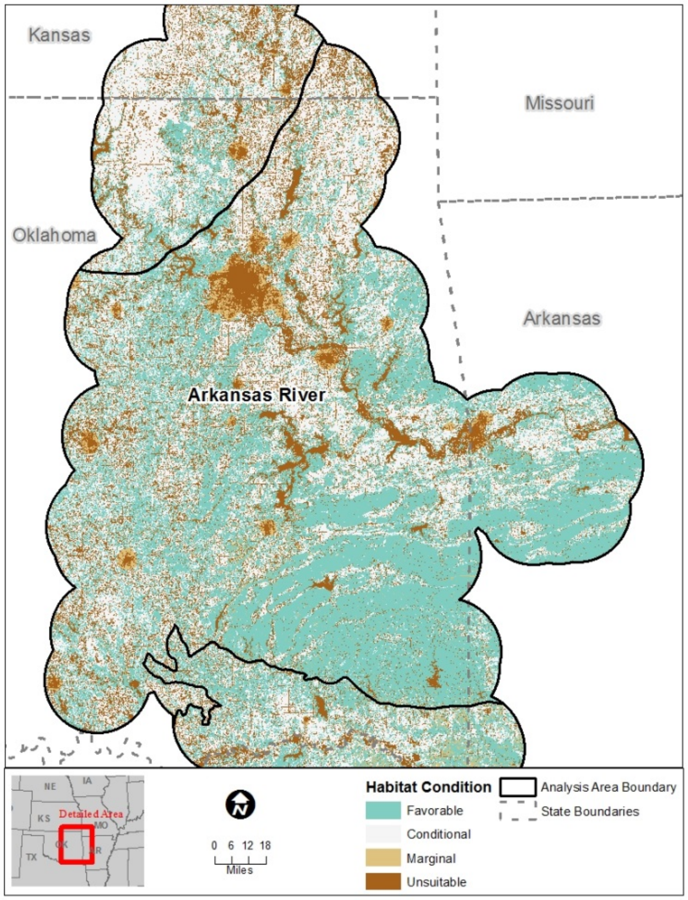


Figure 4-4. American burying beetle habitat condition in the Arkansas River Analysis Area

Of the total analysis area, favorable habitat comprises 46%, conditional habitat 33%, marginal habitat 3% and unsuitable habitat is 5.5%. This analysis area supports the largest area of known occupied ABB habitat in the southern portion of the range and includes at least three areas with concentrations of positive surveys. The three areas of known ABB concentrations include Fort Chaffee, Cherokee and Flanagan Prairie Natural Areas in Arkansas, Camp Gruber/Cherokee Wildlife Management Area (Oklahoma), and a large undefined area focused around counties of Coal, Hughes, Pittsburg and portions of surrounding counties in south central Oklahoma. This south central concentration includes the McAlester Army Ammunition Plant and several Oklahoma Department of Wildlife Conservation (ODWC) wildlife management areas (WMA). Other portions of the Arkansas River Analysis Area, such as Creek and Pushmataha Counties, have areas with concentrations of positive surveys, but ABB survey information is more limited in other parts of this analysis area and numbers or areas of concentrated positive surveys remain uncertain.

This large analysis area includes diverse land cover types and habitat that ranges from old mountains to prairies. Most of these cover types have at least some positive ABB surveys, but they are not all equal in suitability for ABBs. Large portions of the analysis area are dominated by a mixture of forest types (8,396,038 acres or 47%) and most forested habitat is considered favorable for ABBs. However, intensively managed pine plantations and forested areas in the mountain ranges of Oklahoma and Arkansas tend to be marginal due to plantation management practices and thin rocky soils in the old mountain ranges. The existing surveys in the mountains have low catch rates that indicate they are poor habitat for ABBs. Other portions of this analysis area are dominated by grassland/pasture lands with some trees and shrub cover (7,575,114 acres or 43%). Most of these grassland/pasture lands are considered conditional habitat and support agricultural uses like grazing and hay production that can affect habitat suitability. The large percentage of conditional habitat makes the ABB population in this analysis area more sensitive to changes in land uses such as grazing or haying that affect the habitat suitability. There are areas dominated by cropland, but they comprise only 2.4% of the analysis area. Urban areas are relatively minor in area (4.4%), but these urban areas are dominated by developed land covers and the analysis area includes cities like Tulsa, Muskogee, and McAlester in Oklahoma and Ft. Smith in Arkansas. Most of the cropland and developed lands are considered unsuitable ABB habitat.

Oil and gas activity is locally high in portions of this analysis area, but minor compared to agricultural land uses. In Oklahoma, an Industry Conservation Plan (ICP) was developed to streamline ESA compliance for the oil and gas Industry. The ICP covers most of the combined Red River, Arkansas River, and Flint Hills analysis areas, but most of the activity and all of the mitigation has been in the Arkansas River Analysis Area. To date (about 3 years), 357 acres of occupied or assumed ABB habitat have been permanently impacted by activities covered in the ICP, 602 acres have been converted to another habitat type (e.g., from forest to grassland) still suitable for the ABB, and 1,459 acres impacted temporarily (restored to suitable ABB habitat within five years). Over 1,800 acres of permanent mitigation has been established at two conservation banks through the ICP. Both conservation banks are in the Arkansas River Analysis Area.

Current risk factors include habitat loss/alteration due to agricultural land uses (mostly grazing with some areas of row crops), commercial forestry, energy related projects, and some areas of urban expansion. For example, urban expansion from the Fort Smith area in Arkansas and intensive agricultural uses in the Arkansas River floodplain, have limited suitable habitat near Ft Chaffee. Urban expansion near Tulsa, Oklahoma has reduced suitable habitat and connectivity between the Arkansas River and Flint Hills Analysis Areas. Some portions of the analysis area are more affected by habitat loss and alteration than others, which may explain why many areas of potential habitat have few or no positive ABB surveys. Temperature and precipitation changes associated with climate change, as discussed in Chapter 3, could also affect habitat suitability and potentially reduce or eliminate ABB use of large areas (especially the southern portions) in this analysis area. Portions of this analysis area are near the southern and western edge of the known ABB range and thresholds for temperature and moisture limits could be approached or exceeded with potential climate changes in future years, but no obvious climate–related impacts are currently apparent.

4.2.3 Flint Hills

The Flint Hills Analysis Area includes 3,706,908 total acres with 2,846,079 acres of potential habitat (combined favorable, conditional and marginal land cover types, see Table 4-1) in portions of Kansas and Oklahoma (Figure 4-5).

Of the total analysis area, favorable habitat comprises 18%, conditional habitat 58%, marginal habitat 0.1% and unsuitable is 4.3%. Some portions of the analysis area are dominated by a mixture of forest types (705,816 acres or 19%) that are mostly favorable habitat, but large portions are dominated by grassland/pasture lands with some percentage of trees and shrub cover (2,483,628 acres or 67%). Most of these grassland/pasture lands are considered conditional habitat and support agricultural uses like grazing and hay production that can affect habitat suitability. The large percentage of conditional habitat makes the ABB population in this analysis area more sensitive to changes in land uses that affect the habitat suitability. There are areas dominated by cropland, but they are only 8% of the analysis area. Urban areas are relatively minor in area as well (4%), but multiple small urban areas are dominated by developed land covers. Most of the cropland and developed lands are considered unsuitable ABB habitat.

Current risk factors include habitat loss/alteration due to agricultural land uses (mostly grazing with some areas of row crops), and some areas of urban expansion. Much of this analysis area is dominated by native grasslands and livestock grazing is the primary land use. Alterations through intensive grazing, annual burning, and herbicide use to control forbs and woody vegetation are potentially affecting habitat suitability for carrion sources and ABBs. Climate change could also affect habitat suitability and potentially reduce or eliminate ABB use of large areas (especially the southern portions) in this analysis area. Portions of this analysis area are near the southern and western edge of the known ABB range and thresholds for temperature and moisture limits could be approached or exceeded with potential climate changes in future years.

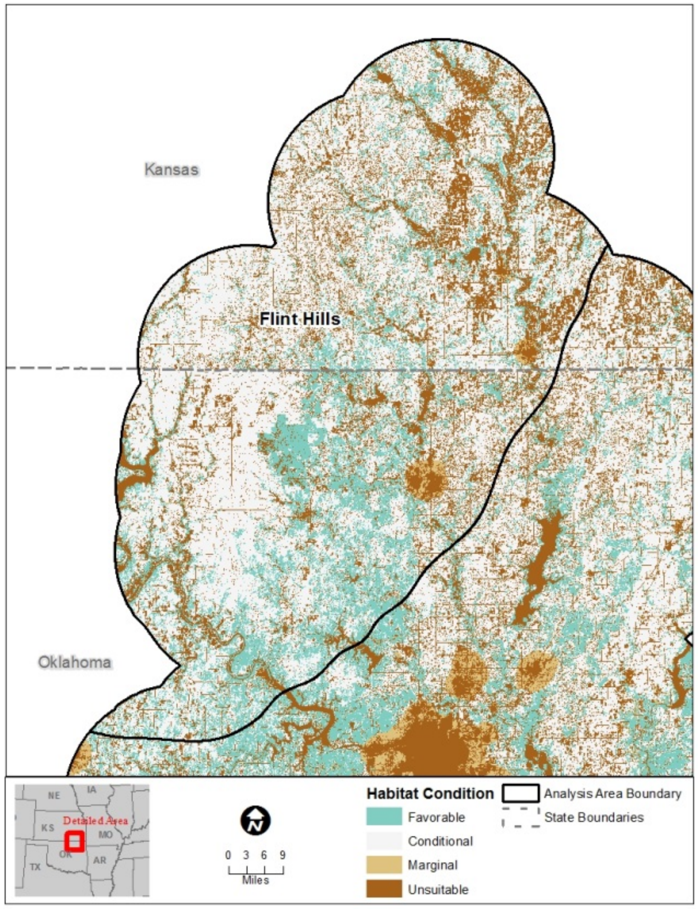


Figure 4-5. American burying beetle habitat condition in the Flint Hills Analysis Area

4.2.4 Loess Canyons

The Loess Canyons Analysis Area includes 2,758,610 total acres with 1,686,948 acres of potential habitat (combined favorable, conditional and marginal land cover types, see Table 4-1) in southcentral portions of Nebraska (Figure 4-6). Of the total analysis area, favorable habitat comprises 30%, conditional habitat 31%, marginal habitat 0.8% and unsuitable 2.6%. Small portions of the analysis area are dominated by a mixture of forest types (about 3%) but large portions are dominated by grassland/pasture lands with some trees and shrub cover (1,733,819 acres or 63%). Most of these grassland/pasture lands are considered conditional habitat and support agricultural uses like grazing and hay production that can affect habitat suitability. However, grazing in the Nebraska and South Dakota analysis areas does not seem to have the same negative effect on ABB numbers or presence (relative to southern analysis areas), possibly because potential carrion sources are different in northern analysis areas and some may be adapted to shorter grasslands (see discussion in Chapter 3, section 3.1. There are large areas dominated by cropland (823,068 acres), that represent 30% of the analysis area. Urban areas are relatively minor in area (2%), but multiple small urban areas are dominated by developed land covers. Most of the cropland and developed lands are considered unsuitable ABB habitat.

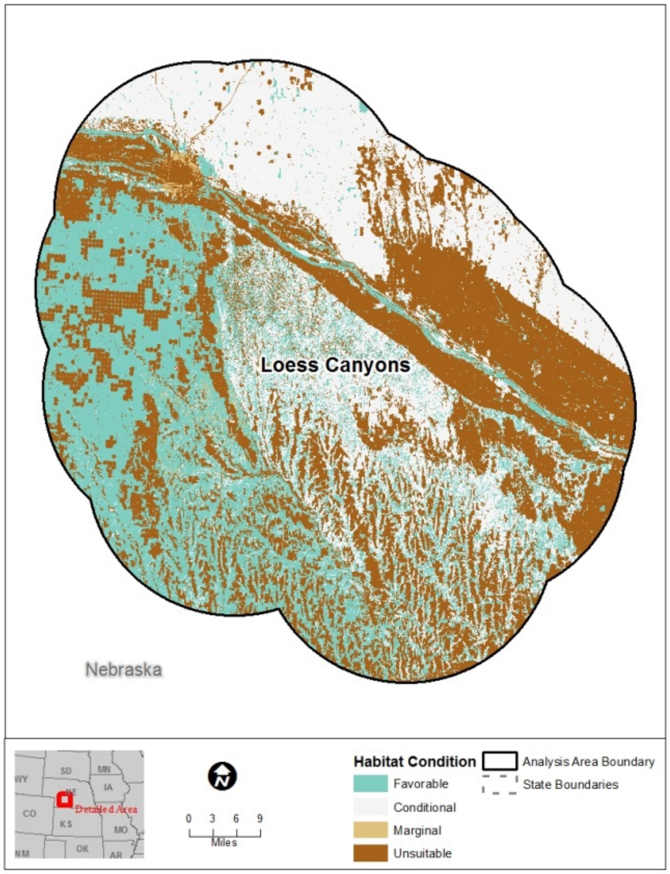


Figure 4-6. American burying beetle habitat condition in the Loess Canyons Analysis Area

Current risk factors include habitat loss and alteration due to agricultural land uses (mostly conversion of grassland to row crops), and some areas of urban expansion. Because of fire suppression, native eastern redcedar, Juniperus virginiana L., is invading many grassland areas in the Loess Canyons. In the past 30 years, cedar encroachment has covered more than 30% of this landscape and is increasing at a rate of 2% per year. The effects of cedar trees on remaining populations of ABB are currently unknown, but Walker and Hoback 2007 (pages 300-303), collected significantly more Silphidae, including ABB in open habitats. Among the Silphidae, only Nicrophorus orbicollis was collected significantly more often in cedar areas.

Much of this analysis area is dominated by native grasslands and livestock grazing is the primary land use. Alterations through conversion to cropland (Figure 4-7) and expansion of invasive woody vegetation are potentially affecting habitat suitability for carrion sources and ABBs. Climate change could also affect habitat suitability and potentially reduce or expand ABB use of portions of this analysis area. Portions of this analysis area are near the western edge of the known ABB range and changes in temperature and moisture could reduce the suitable habitat area in future years.

Most of the potential conversion of ABB habitat to cropland requires irrigation in Nebraska and South Dakota analysis areas. Irrigation supports crop development in semiarid areas and areas with sandy soils. Some regions, like southeastern Nebraska, have seen steep rises in irrigated farmland, from around 5% to more than 40%, during the 1950-2002 time period.

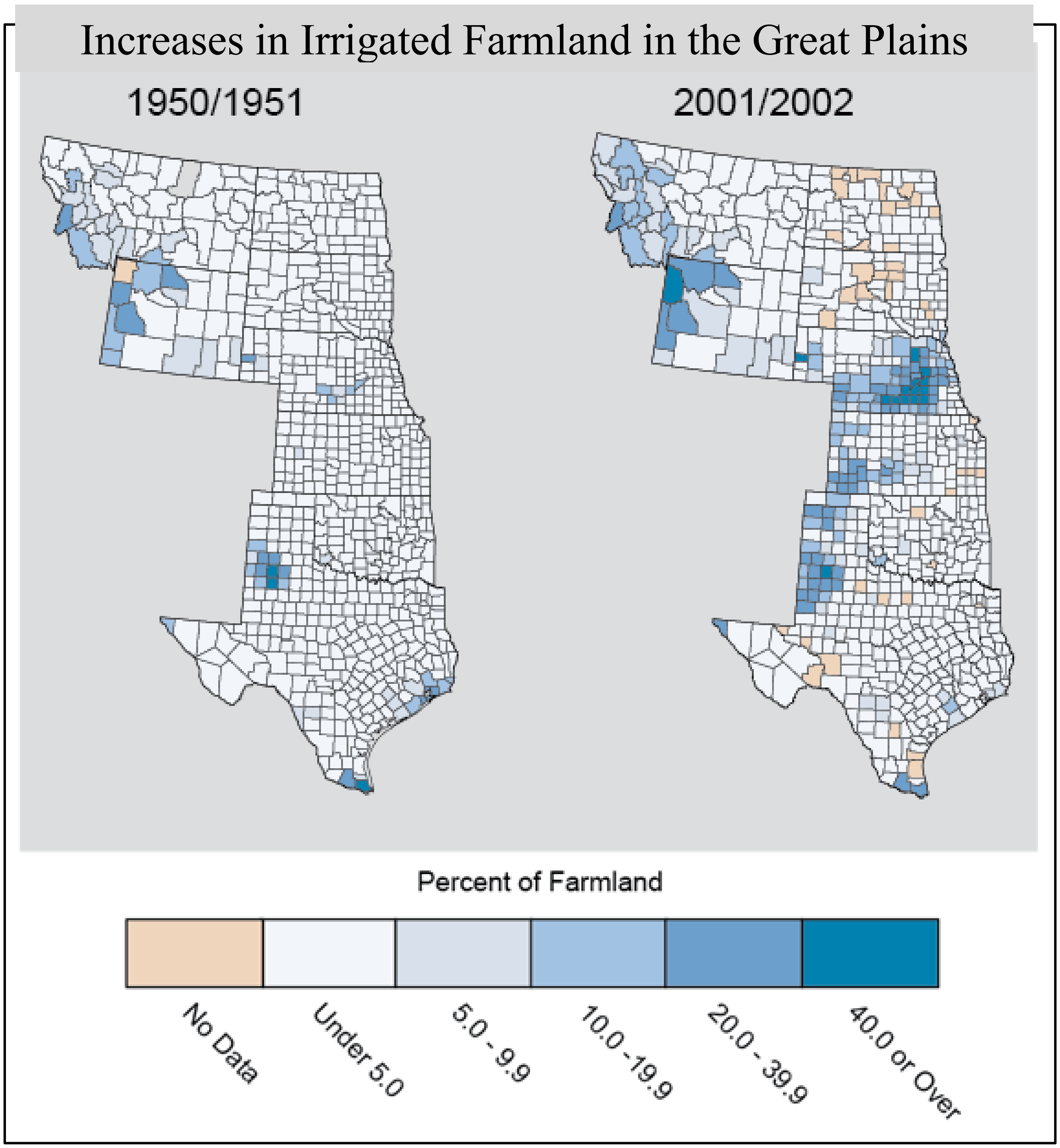


Figure 4-7. Irrigation supports crop development in semiarid areas. Some aquifer-dependent regions, like southeastern Nebraska, have seen steep rises in irrigated farmland, from around 5%

to more than 40%, during the period shown. (Figure source: reproduced from Atlas of the Great Plains by Stephen J. Lavin, Clark J. Archer, and Fred M. Shelley by permission of the University of Nebraska. Copyright 2011 by the Board of Regents of the University of Nebraska).

4.2.5 Sandhills

The Sandhills Analysis Area is the second largest analysis area and includes 10,819,170 total acres with 8,633,685 acres of potential habitat (combined favorable, conditional and marginal land cover types, see Table 4-1) in northcentral portions of Nebraska (Figure 4-8). Of the total analysis area favorable habitat comprises 10%, conditional habitat 70%, marginal habitat 0.2% and unsuitable 20%. Small portions of the analysis area are dominated by a mixture of forest types (about 3%) but large portions are dominated by grassland/pasture lands with some percentage of trees and shrub cover (7,899,142 acres or 73%). Most of these grassland/pasture lands are considered conditional habitat and support agricultural uses like grazing and hay production. However, grazing in the Nebraska and South Dakota analysis areas does not seem to have the same negative effect on ABB numbers or presence (relative to southern analysis areas), possibly because there are different potential carrion sources in the northern analysis areas. Potential carrion sources in northern analysis areas, such as native grouse, prairie dogs and ground squirrels, may be adapted to shorter grasslands. The effects of grazing and the differences between Northern and Southern Plains analysis areas are also discussed in Chapter 3, section 3.1. There are large areas dominated by cropland (1,434,183 acres), which represent 13% of the analysis area. Urban areas are relatively minor in area (1%), but multiple small urban areas are dominated by developed land covers. Most of the cropland and developed lands are considered unsuitable ABB habitat.

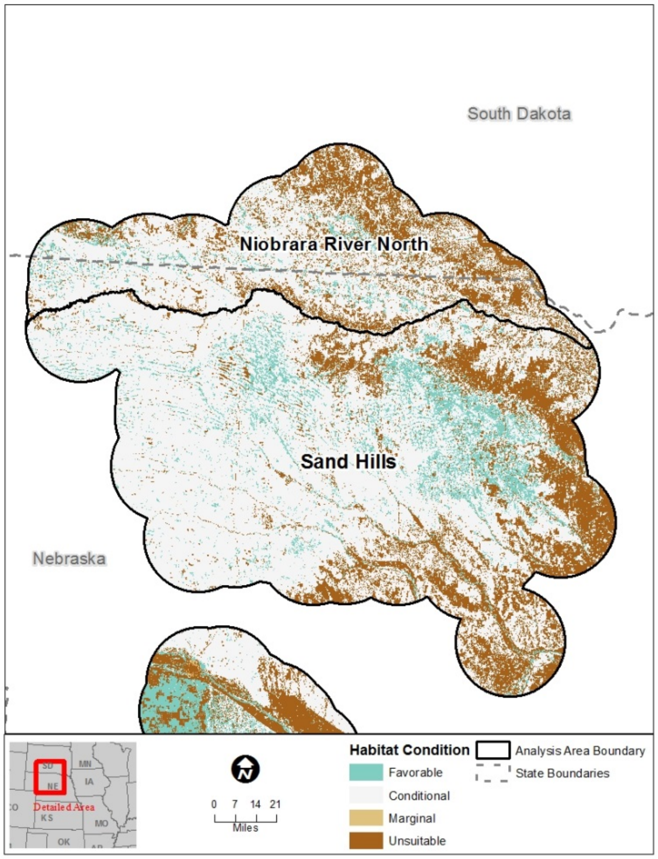


Figure 4-8. American burying beetle habitat condition in the Sandhills and Niobrara Analysis Areas.

Current risk factors include habitat loss/alteration due to agricultural land uses (mostly conversion of grassland to row crops), and some areas of urban expansion. Wind energy development has increased in recent years and may become a much larger risk in the future. Wind turbines and associated roads and powerlines have direct and indirect adverse effects that have not been assessed. Much of this analysis area is dominated by native grasslands and livestock grazing is the primary land use. Alterations through intensive grazing, conversion to irrigated cropland (see Figure 4-7), and expansion of invasive woody vegetation are potentially affecting habitat suitability for carrion sources and ABBs. Most of the potential conversion of ABB habitat to cropland requires irrigation in Nebraska and South Dakota analysis areas. Increased irrigation or other uses of ground water are a risk if they exceed recharge rates and lower the water table. Declining aquifer levels would threaten the habitat suitability in this analysis area because soil moisture is maintained by water tables that are relatively near the surface.

Climate change could also affect habitat suitability and potentially reduce or expand ABB use of portions of this analysis area. Portions of this analysis area are near the northern and western edge of the known ABB range and changes in temperature and moisture could affect suitable habitat in future years.

4.2.6 Niobrara River

The Niobrara River Analysis Area includes 4,108,903 total acres with 2,961,469 acres of potential habitat (combined favorable, conditional and marginal land cover types, see Table 4-1) in northcentral portions of Nebraska and southcentral South Dakota (Figure 4-8). Of the total analysis area favorable habitat comprises 6%, conditional habitat 65%, marginal habitat 0.44% and unsuitable 28%. Small portions of the analysis area are dominated by a mixture of forest types (about 5.33%) but large portions are dominated by grassland/pasture lands with some trees and shrub cover (3,040,447 acres or 74%). Most of these grassland/pasture lands are considered conditional habitat and support agricultural uses like grazing and hay production that can affect habitat suitability. However, grazing in the Nebraska and South Dakota analysis areas does not seem to have the same negative effect on ABB numbers or presence (relative to southern analysis areas), possibly because potential carrion sources in northern analysis areas are different and some (like prairie dogs and ground squirrels) may be adapted to shorter grasslands. The effects of grazing and the differences between Northern and Southern Plains analysis areas are also discussed in Chapter 3, section 3.1. There are large areas dominated by cropland (534,133 acres) that represent 13% of the analysis area. Urban areas are relatively minor in area (2%), but multiple small urban areas are dominated by developed land covers. Most of the cropland and developed lands are considered unsuitable ABB habitat.

Current risk factors include habitat loss and alteration due to agricultural land uses (mostly conversion of grassland to row crops), and some areas of urban expansion. Most of the potential conversion of ABB habitat to cropland requires irrigation in Nebraska and South Dakota analysis areas. Increased irrigation or other uses of ground water are a risk if they exceed recharge rates lowering the water table. Declining aquifer levels would threaten the habitat suitability in this analysis area because soil moisture is maintained by water tables that are relatively near the surface. Much of this analysis area is dominated by native grasslands and livestock grazing is the primary land use. Alterations through conversion to irrigated cropland (Figure 4-7) and expansion of invasive woody vegetation are potentially affecting habitat suitability for carrion sources and ABBs. Climate change could also affect habitat suitability and potentially reduce or expand ABB use of portions of this analysis area. Portions of this analysis area are near the northern and western edge of the known ABB range and changes in temperature and moisture could affect suitable habitat in future years.

4.2.7 New England

The New England Analysis Area consists of two islands where ABB are known to occur: Block Island, RI and Nantucket, MA. Of the total analysis area, favorable habitat comprises 31%, conditional habitat 22%, and marginal habitat 8%, while the remaining 39% is considered unsuitable. Land use and habitat types are similar on these two islands. Block Island is 6,111 acres in size, and is mostly comprised of conservation lands (2,523 acres; 41%) and residential areas (1,957 acres; 32%) (Figure 4-9). Nantucket, 36,321 acres in size, is similar, with a large proportion held by land trusts and classified as brushland/early successional habitat.

The Block Island population occurs on glacial moraine deposits vegetated with a post-agricultural maritime scrub plant community. Vegetation includes extensive stands of bayberry

(*Myrica*), shadbush (*Amelanchier*), goldenrod (*Solidao*), and numerous exotic plant species. Vegetation structure varies from shrub thickets to large mowed and grazed fields. Block Island was totally deforested by the mid-1700's (Livermore 1877, p. 24–27), and only in very recent decades has vigorous woody growth reappeared following the abandonment of grazing and agricultural practices (USFWS 1991, p. 13).

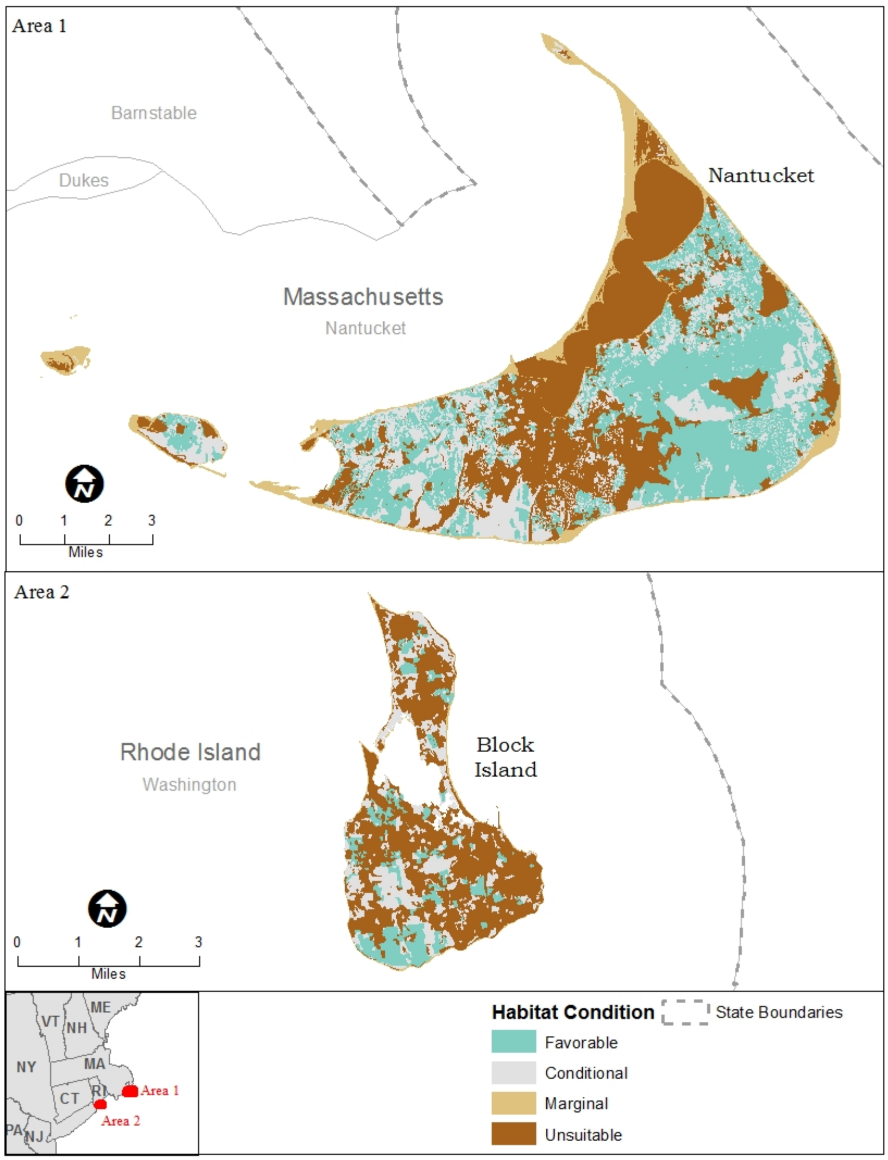


Figure 4-9. American burying beetle habitat condition on Block Island, RI and Nantucket Island, MA.

4.2.8 Assessing Habitat Fragmentation

Land conversion to agriculture, intensive domestic livestock grazing, logging, fire suppression, wind energy development and urban development are common causes of habitat loss and fragmentation within the current ABB range. For example, large areas of native grasslands have been converted to introduced non-native grasses such as fescue and bermuda grass varieties to improve pastures for intensive cattle grazing operations. Even in areas with native vegetation, pastures and hay fields can be more intensely grazed or mowed during drought periods when demand for grass/hay is high, which can keep habitat in an unfavorable or marginal condition for longer time periods. Our available land cover data was not adequate for measuring the current habitat suitability and effects of fragmentation related to these for these types of land uses.

However, we did assess potential fragmentation effects in other ways. For example, we reduced habitat suitability in buffers around urban areas to account for habitat impacts related to urban expansion. For resiliency assessments we looked at locations of urban areas in relation to concentrations of ABBs to assess current and future risks. Concentrations of positive ABB surveys are an indication that habitat is relatively contiguous and that fragmentation is not excessive. For example, areas with high densities of row crop or other unfavorable habitat tend to have few positive surveys and can indicate high levels of fragmentation. We also made assumptions about conditional habitat like pastures and hay fields to account for land uses that can make habitat temporarily or seasonally unfavorable. Our available land cover data can't provide exact information on what areas are temporarily unfavorable or for how long and these areas could constantly shift or vary, but we assumed percentages of these land covers would be in an unfavorable condition at any given time (where appropriate). More justifications for these assumptions are provided in Chapter 5, section 5.2.1.2 and in discussions of each analysis area.

We also considered the potential for fragmentation based on the quantity and location of the land use. For example, the potential for significant fragmentation due to cropland in most of the Arkansas River Analysis Area is limited because there are a few areas dominated by cropland, but they tend to be concentrated and comprise only 2.4% of the analysis area. The same factors apply to urban development because they comprise only 4.4% of that analysis area and most urban areas are not located near ABB concentrations.

4.3 PROTECTED LANDS

Most populations throughout the ABB's range are located on private lands with no long-term, assured protections of suitable habitat. However, there are some public and/or protected lands that are either known to have ABBs present on or have the potential to support ABBs. These protected lands were classified as managed, multi-use, tribal or other to represent their level of protection.

Managed - Lands are assumed to have management plans that incorporate active management with the primary purpose of maintaining or improving wildlife habitat and would protect or improve ABB habitat.

Multi-use- Lands are assumed to be managed for mixed purposes and may include some management for wildlife that would protect or improve ABB habitat.

Tribal – Lands owned or managed by Native American tribes. Management is variable and controlled by individual tribes. Active management for wildlife is usually included for some portion of these lands.

Other – Lands are not known to be managed or are utilized for purposes that would not provide any protection for ABB habitat.

The Red River Analysis Area has 123,779 acres of managed and 23,997 acres of multi-purpose protected lands. Protected areas include U.S. Forest Service, USFWS National Wildlife Refuge, ODWC wildlife management area lands, but only one is currently known to support ABBs, (see Table 4-2 Protected Lands, Figure 4-10).

The Arkansas River Analysis Area has several relatively large blocks of protected lands represented by Federal and state ownership and 2 large conservation banks that are privately owned. Within the Arkansas portion of the analysis area, Fort Chaffee and Ozark-St. Francis and Ouachita National Forests have conservation plans in place that provide some level of protection, management, and monitoring for ABB. Multiple federal, state, tribal and private lands and conservation banks) areas in Oklahoma have some level of protection, and management. The analysis area has 1,486,002 acres of managed lands and 933,608 acres of multi-purpose protected lands (Table 4-2, Figure 4-10).

The Flint Hills Analysis Area has several relatively large blocks of protected lands represented by Federal, tribal, and state ownership, and over 40,000 acres in the Tallgrass Prairie Preserve managed by The Nature Conservancy (TNC). The analysis area has 133,196 acres of managed and 52,114 acres of multi-purpose protected lands. It also has over 43,000 acres of tribal lands (Table 4-2, Figure 4-10).

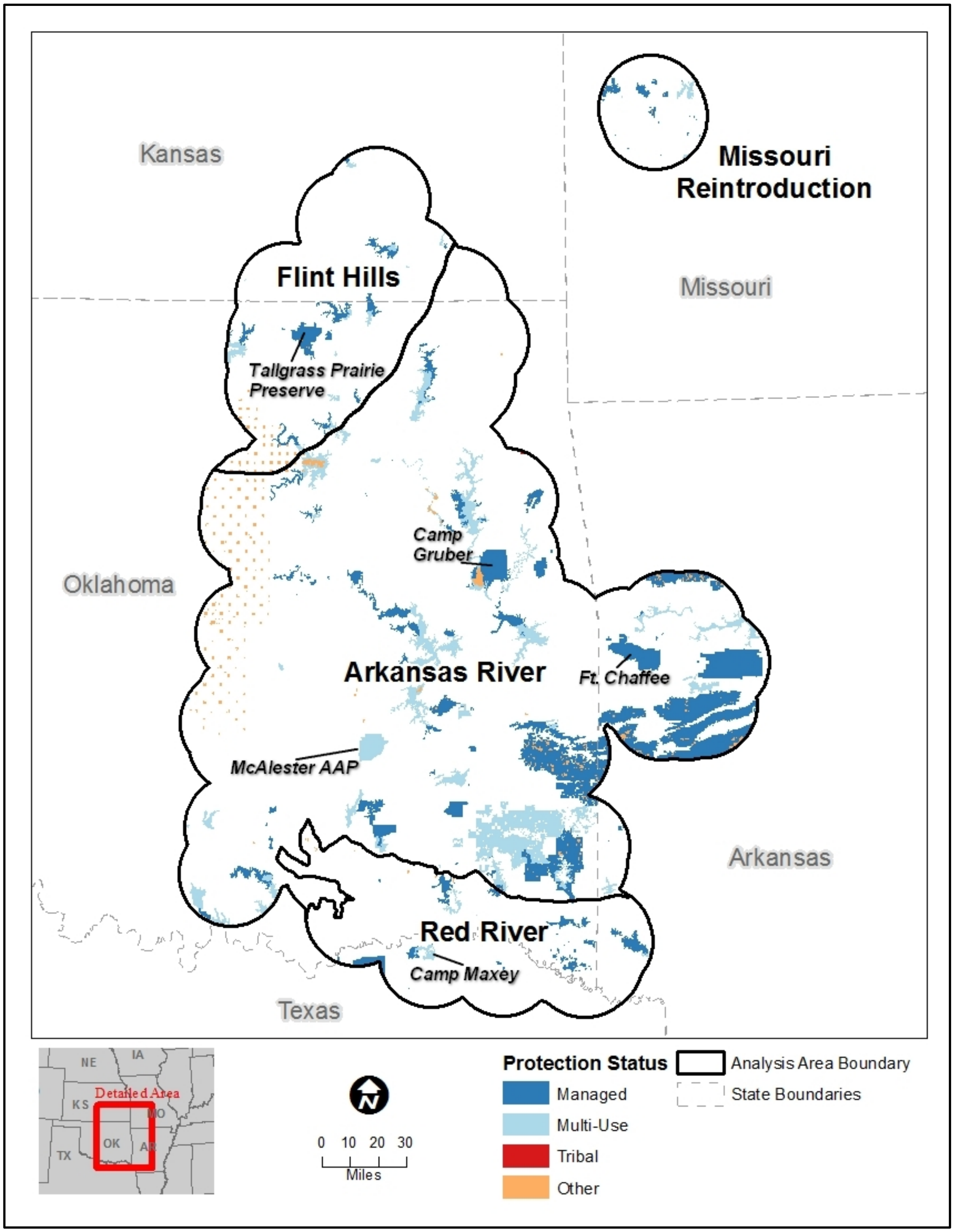


Figure 4-10. Protected areas within the Red River, Arkansas River, and Flint Hills Analysis Areas.

The Loess Canyons Analysis Area has 15,342 acres of managed and 3,843 acres of multi-purpose protected lands (Table 4-2, Figure 4-11).

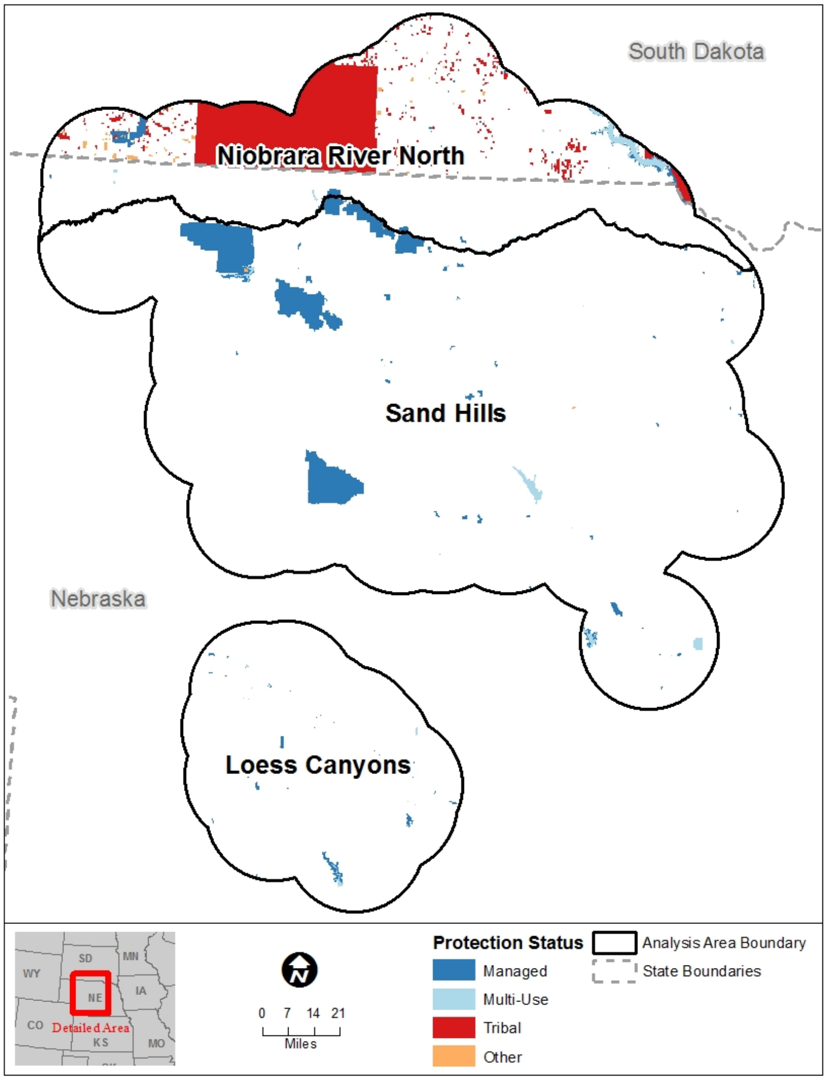


Figure 4-11. Protected areas within the Loess Canyons, Sandhills, and Niobrara Analysis Areas.

The Sandhills Analysis Area has 393,983 acres of managed and 24,633 acres of multi-purpose protected lands (Table 4-2, Figure 4-11).

Most of the Niobrara River Analysis Area is private land with no known level of protection, but this analysis area does have some protected areas. The Niobrara River Analysis Area has 58,918 acres of managed, 33,582 acres of multi-purpose, and 765,896 acres of tribal protected lands (Table 4-2, Figure 4-11). In South Dakota there are two small state-owned game production areas that are in public ownership with known occurrences of ABB. The eastern edge of the Niobrara River Analysis Area also has several state-owned game production areas, but ABBs have not been found in these areas. The managed land on the western edge is LaCreek National Wildlife Refuge which has been surveyed for ABB, but none have been found there. The tribal lands to the west (Todd County) do not provide specific protection for ABB, but most of this land is rangeland and less likely to be converted to other land uses.

The New England Analysis Area consists of two islands where ABB are known to occur: Block Island, RI and Nantucket, MA. Block Island is 6,111 acres in size, and has a large area of conservation lands (2,523 acres; 41%). Nantucket, 36,321 acres in size, is similar, with a large proportion held by land trusts or other protected status (11,934 acres; 33%). Combined there is a total of 42,431 acres with 25,865 suitable habitat acres and 14,457 acres of protected lands.

Table 4-2 provides a summary of our analysis of protected lands within the analysis areas. With the exception of the New England Analysis Area, protected lands are a small percentage of all lands within the analysis areas. The importance of protected lands is discussed later in this chapter within the current conditions for each analysis area. The information for protected lands in New England includes both Block and Nantucket Islands.

Table 4-2. Area of Protected Lands (Acres) and Percent of the Analysis Area

Analysis Area	**Managed Lands**	**Multi-Use Lands**	**Tribal Lands**	**Other Protected Lands**	**Total Protected Lands**
Red River	123,779 (3.8%)	23,997 (.7%)	None	3,523 (0.1%)	151,299 (4.6%)
Arkansas River	1,486,002 (8.4%)	933,608 (5.3%)	1,590 (0.009%)	140,371 (0.8%)	2,561,571 (14.4%)
Flint Hills	133,196 (3.6%)	52,114 (1.4%)	43,000	22,165 (0.6%)	250,475 (6.8%)
Loess Canyons	15,342 (0.6%)	3,843 (0.1%)	None	182 (0.007%)	19,367 (0.7%)
Sandhills	393,983 (3.6%)	24,633 (0.2%)	None	952 (0.009%)	419,568 (3.9%)
Niobrara River	58,918 (1.4%)	33,582 (0.8%)	765,896 (18.6%)	14,669 (0.4%)	873,065 (21.2%)
New England	13026 (30.7%)	1,310 (2.9%)	None	121 (0.3%)	14,457 (34%)

4.4 POPULATION STATUS

Because we have limited information by which to measure ABB population abundance, we assessed a range of population conditions to allow us to consider the species' resiliency, redundancy, and representation. The primary indicators of resiliency are geographic distribution of ABBs within analysis areas and relative abundance, based on ratios of positive to negative surveys within an analysis area. Factors such as carrion availability would be appropriate to consider, but carrion abundance or availability can be highly variable and are not commonly monitored across the analysis areas. We assume reproductive success and relative abundance would indirectly represent the availability of appropriate carrion.

4.4.1 Broad ABB Survey Assessment

Numerous ABB surveys have been conducted throughout the six western analysis areas - Red River, Arkansas River, Flint Hills, Loess Canyons, Sandhills, and Niobrara River. The majority of these surveys are undertaken to determine whether ABBs are located in areas with anticipated soil disturbing actions associated with development projects. As such, most survey data within these analysis areas are collected sporadically and without a large geographic systematic approach.

To analyze these data and gather general comparisons between analysis areas, we compared the ratio of positive to negative surveys from the last 15 years (2001-2015) (Table 4-3). By doing so, we are able to compare capture rates between analysis areas, which we view as indicative of relative abundance.

Table 4-3. Total survey effort from 2001-2015 in each of the 7 analysis areas.

	Positive Surveys	Negative Surveys	Percent Positive
Red River	93	903	9.3%
Arkansas River	1278	3640	26.0%
Flint Hills	191	1171	14.0%
Loess Canyons	209	492	29.8%
Sand Hills	910	920	49.7%
Niobrara	131	296	30.7%
New England	na	na	na

*Survey information from New England was not comparable to other areas, therefore was not analyzed.

The Sandhills in Nebraska had the overall highest positive/negative ratio at 49.7%, suggesting that approximately half of the surveys within that analysis area result in the collection of at least one ABB. This value is based on an overall average of surveys within the analysis area, so should not be considered a probability of capture at any one location. The Niobrara, Loess Canyon, and Arkansas River were somewhat similar in overall positive/negative surveys, with values of 30.7%, 29.8%, and 26.0%, respectively, followed by the lowest values from Flint Hills at 14.0% and Red River at 9.3%.

To better visualize the data, we conducted an interpolation analysis of the presence/absence data (Kriging, ArcGIS 2016), which allowed us to assess potential areas of relatively high capture rates and how those areas are distributed within each analysis area (Figure 4-12). Because of difference in survey methods through the years and limitations to the survey data, we used the interpolation analysis only as an observational assessment rather than a quantifiable statically analysis. Despite its limitations, important observations on capture rates and distribution can be inferred.

Most observable is the broad distribution of high capture rates in the Sandhills area, with relatively little clustering as compared to the Arkansas River area (Figure 4-12). The Loess Canyons and Niobrara River areas have a much smaller areas of high capture rates that are focused near the middle of the analysis areas. The Flint Hills and Red River areas show the smallest area with high capture rates, but were somewhat different in their clustering.

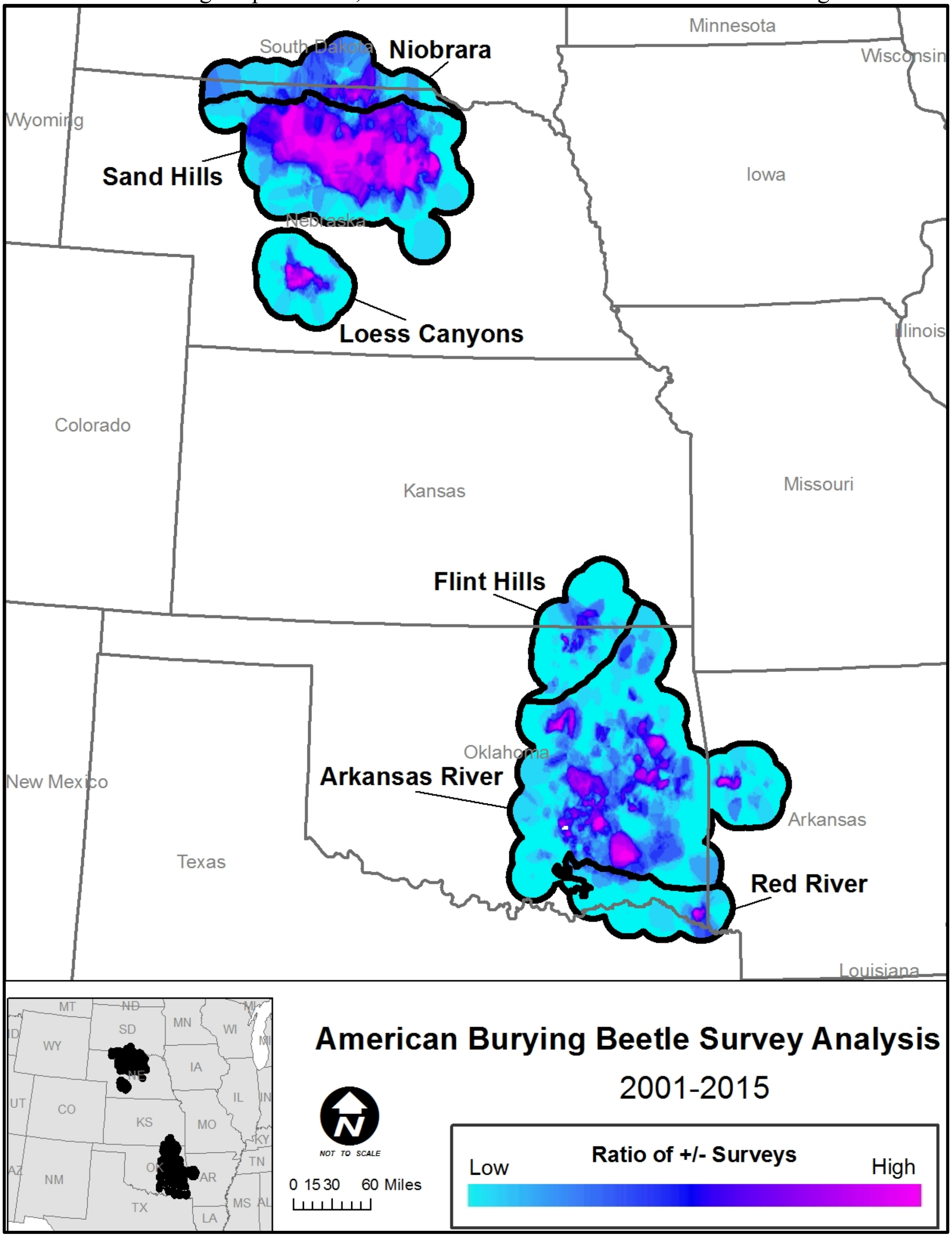


Figure 4-12– Kriging interpolation analysis assessing ratio of positive to negative surveys.

The Red River area appears to have one small cluster in the eastern portion (using the last 15 years of data, but no clusters in more recent years), whereas the Flint Hills has multiple small clusters.

4.4.2 Site Specific Population Accounts

Although surveys are distributed throughout each analysis area and are useful for evaluating general population differences between analysis areas, we have limited areas with frequent, replicative surveys and even fewer areas with population estimates based on mark and recapture studies. These areas provide important information about the ABB status as a local level and reflect annual fluctuations in ABB numbers. Relatively large fluctuations have been documented at monitored sites and are expected. Because the ABB completes its lifecycle in one year, each year's population levels are largely dependent on the reproductive success of the previous year and reproductive conditions in the current year. Fluctuations are thought to be a function of the abundance of the carrion resources on which they depend. Therefore, populations may be cyclic (due to weather, disease, etc.), with high numbers and abundance in one year, followed by a decline in numbers the succeeding year. These short-term stochastic events would not necessarily have long-term effects for populations (USFWS 2008a, p. 33; Amaral et al. 2005, p. 8).

Red River Analysis Area

No positive surveys within this analysis area have been documented in Arkansas or Texas and only 8 positive surveys are known in Oklahoma since 2008. From the available survey data, populations appeared to be declining by 2008, but survey effort has been limited in most of the Red River Analysis Area in recent years (Figure 4-13).

There is some evidence that the small population of ABBs known to occur in northern Texas, may be declining (USFWS 2008a) or may be extirpated. In Texas, the ABB has been found on Camp Maxey, Lamar County (Figure 4-13) from 2003 - 2008, and an ABB was documented at the Nature Conservancy's Lennox Woods, Red River County in 2004. No ABBs have been documented at Camp Maxey from 2009 - 2017, despite intensive surveying.

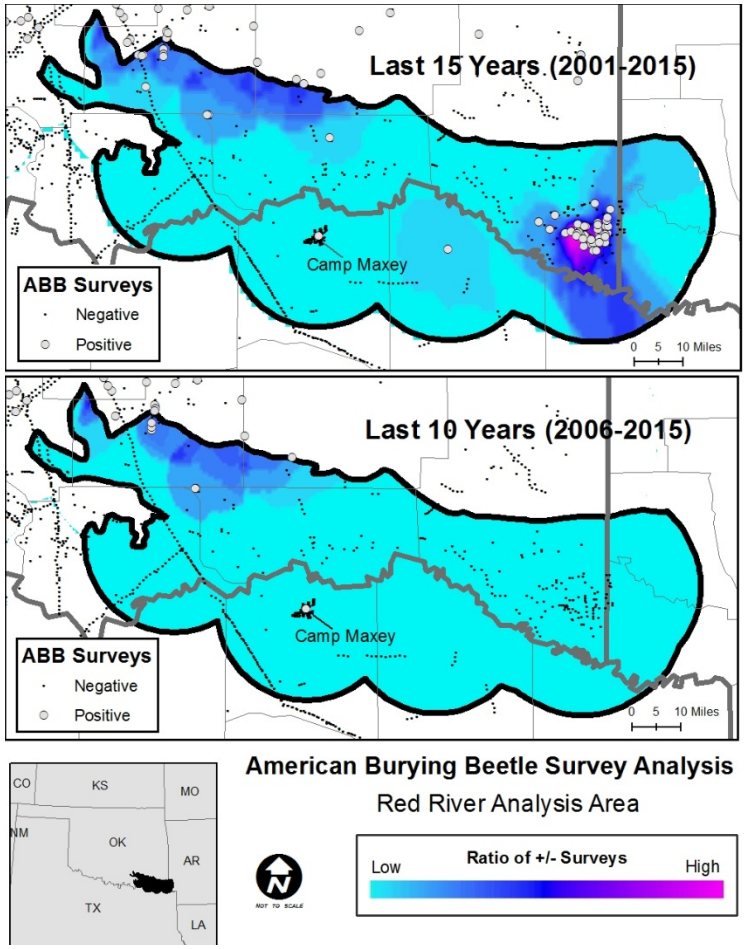


Figure 4-13. Kriging interpolation analysis showing areas of low versus high capture rates for two time periods.

The decline of ABBs in Texas and portions of this analysis area could represent the effects of climate changes, however historical documentation of ABBs in Texas is limited and does not provide any population-related information prior to 2003. The Texas ABB population was historically only known from a single specimen attributed to Kingsville, TX (south Texas) because it was part of a collection donated from there, but it is questionable if the specimen was actually collected from Kingsville, TX. Four additional Texas specimens from the 1880's were discovered at The Academy of Natural Sciences of Drexel University Invertebrate Collection, but no recent confirmed ABB records in Texas, until 2003 when a single specimen was found at Camp Maxey in Lamar County. No routine surveys for carrion beetles had previously been conducted at Camp Maxey, so it is likely ABBs occurred there, at least periodically, in previous years. In 2005 another 223 ABB individuals were captured in pitfall traps at Camp Maxey. After 2005, the population of ABBs and N. *orbicollis* started to decline. In 2006, there were 68 ABBs captured, 51 ABBs in 2007, and by 2008 this number decreased to 8 ABBs (Abbott and Abbott 2013, p. 2). The pattern indicates the species is on the decline at Camp Maxey and potentially within its Texas range. In 2008, the trapping effort was tripled because of the previous year's patterns; however, the number of ABB captured during these efforts did not increase. Since 2008 there have been no ABBs captured at Camp Maxey or elsewhere in Texas.

Factors such as the invasion of fire ants could contribute to the ABB decline, but fire ants had become established in the Red River Analysis Area by the 1990s and were present at Camp Maxey when ABB catch rates were relatively high. *Nicrophorus carolinus* may be replacing ABBs and has seen a drastic increase in population abundance (as observed in pitfall traps) at Camp Maxey as ABBs declined since 2008 (Abbott and Abbott 2013, p. 2). *Nicrophorus carolinus* population numbers seem to follow the mean maximum air temp closely (Abbott and Abbott 2013, p. 2) and this species requires higher soil temperatures for reproduction (25° C or 77° F) (Jacques et al. 2009). The fact that *N. orbicollis* also declined at Camp Maxey during the same time period provides additional evidence that climate may have caused the decline in ABBs. The historical geographic range, and presumably the ecological tolerances, of ABBs are most similar to its congener *N. orbicollis* (Sikes and Rathel 2002, p. 109). The similarity in ecological niche (geographic range, diel periodicity, breeding season, *etc*.), and phylogenetic information indicate these species may be each other's closest surviving relatives (Szalanski et al. 2000), and suggest that ABBs and *N. orbicollis* may have similar temperature and ecological tolerances.

A 10 year monitoring study of the ABB on the Weyerhaeuser HCP planning area in McCurtain County, Oklahoma, and Little River County, Arkansas, revealed a decline in ABB captures. Schnell et al. (2008) suggested that although zero ABB captures for the second year in a row could be of concern, they have previously noted substantial year-to-year population fluctuations in the past (e.g., 16 to 106 ABBs during 1997 to 2004). Within the 10 years being summarized, relative densities of ABBs generally declined from an average of 0.076 beetles per trap-night (106 beetles captured) in 1997 to 0.010 beetles per trap-night (16 beetles captured) in 2001. There was a slight increase in 2002 (0.015 beetles per trap-night) and a greater one in 2003 (0.053 beetles per trap-night), but then relative densities dropped again. During 2005-2007, there were no captures of ABBS at regular sites and only one capture in 2005 at a supplemental site. Factors such as the invasion of fire ants could contribute to the ABB decline, but fire ants had become established in the Red River Analysis Area by the 1980s-1990s. Schnell et al. (2006, pg. 3-4) noted an increase in the number of fire ant mounds near trap sites in 2005, but also commented that it was another dry year and catches of all *Nicrophorus* beetles (except *N. tomentosus*) were the lowest on record since the monitoring began in 1997. The decline in ABB densities began several years before the increase in fire ant mounds was noted in 2005. There has been no evidence of a recovery in ABB captures since 2008 in the southern portions of the Red River Analysis Area.

There has been relatively low survey effort in the Red River Analysis Area within the last 10 years and the current status of ABBs in this area is uncertain. The existing information suggests that the ABB population has declined and may be extirpated from portions of this analysis area.

Arkansas River Analysis Area

Fort Chaffee, Camp Gruber, and McAlester Army Ammunition Plant (Figure 4-11) are the only sites within the Arkansas River Analysis Area with frequent monitoring. These areas are all relatively large blocks of protected and managed native habitat with relatively high densities of ABBs in most years. Fort Chaffee contains the largest, most stable population of ABB found in Arkansas and Camp Gruber/Cherokee Wildlife Management Area represents the largest known population in Oklahoma. However, even the largest and most stable ABB areas have fluctuations in numbers.

Annual monitoring at Camp Gruber from 1992 to 2006 illustrates how captures can fluctuate markedly from year to year, with annual total ABBs captured ranging from 81 in 1999 to 754 in 2006. Overall, however, the survey data indicate a stable to increasing population from 1992 to 2006. Record high numbers of ABBs were captured at Camp Gruber between 2004 and 2007. More recent surveys at Camp Gruber in 2012 captured 521 ABBs (61 surveys), and a more limited survey effort in 2014 captured 27 ABBs (15 surveys) and surveys captured near 500 ABBs in 2016.

ABB numbers also fluctuate at Ft. Chaffee, Arkansas. The ten year average (2006-2015) for captures at Ft. Chaffee is 470 ABBs). Figure 4-14 represents some of the fluctuations in ABB survey results. In 2004, only 235 ABBs were captured, followed in 2005 by 849 captures-the second highest capture year to date. Eight hundred and fifty-one beetles were captured at Ft. Chaffee in 2009, the highest number ever recorded on these lands (Ft. Chaffee MTC, 2014). The lowest capture rate occurred in 2012 with only 51 individuals, followed by 353 captures in 2013. ABB captures increased slightly in 2014 and over 650 were captured in 2015. Trapping effort was similar between years.

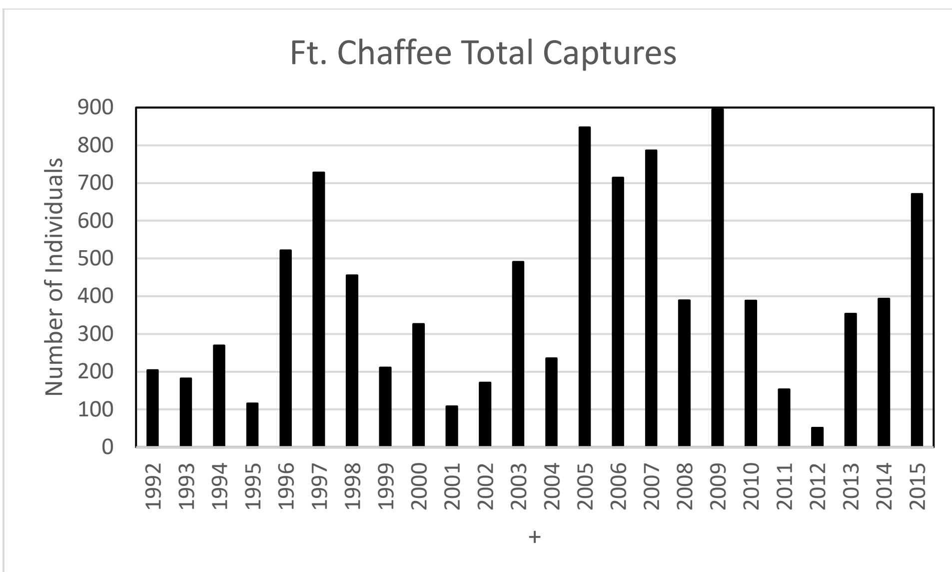


Figure 4-14. Ft Chaffee ABB Survey Results (1992-2015)

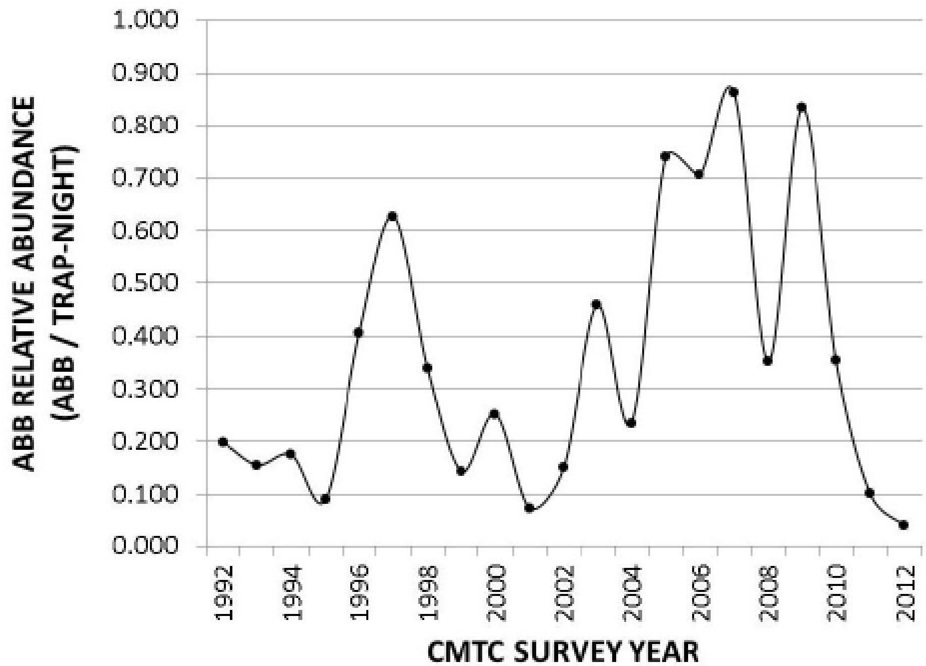


Figure 4-15. Ft Chaffee ABB relative abundances (ABBs/trap-night) from1992-2012 based on a subset of 34 sites that have been consistently surveyed annually over the past two decades.

The Arkansas River Analysis Area contains two conservation banks that are established for compensatory mitigation within Oklahoma. They currently provide about 6,772 acres of land that is protected and managed for ABBs in perpetuity. Information on these banks can be found within the RIBITS database (https://ribits.usace.army.mil/).

ABBs are known to be present on at least portions of public lands within the Arkansas River Analysis Area including: Ozark-St. Francis National Forests, Arkansas; Fort Chaffee, Arkansas; Cherokee and Flanagan Prairie Natural Areas, Arkansas, Ouachita National Forest, Arkansas/Oklahoma; and Camp Gruber/Cherokee WMA, Fort Gibson WMA/Corps lands, Lake Tenkiller WMA/Corps lands, Lake Eufaula WMA/Corps lands, McAlester Army Ammunition Plant, Deep Fork National Wildlife Refuge, Sequoyah National Wildlife Refuge, James Collins WMA, Keystone WMA/Corps lands and portions of the McClellan-Kerr WMA/Corps lands in Oklahoma.

Flint Hills

The Nature Conservancy's Tallgrass Prairie Preserve in Osage County Oklahoma (Figure 4-10) is the only location within this analysis area with significant survey information, and is known to support a relatively large population of ABBs. Studies at the site in 2009 indicated a probable population of between 2,554 - 4,379 beetles, one of the larger remaining extant populations of the insect (Howard and Hall, 2009). Beginning in late summer 2010, Howard and Hall began to document a significant decline in the number of beetles at the site of over 50% in only two years. The 2012 population was estimated to lie between 1,169 and 1,980 beetles across the 16,000 hectares of the preserve. This was an increase from 2011, in which only 47 beetles were captured at the site (Howard and Hall 2012, p. 1). More recently the capture rates had been relatively low with only 23 ABBs captured in 2014 and 27 in 2015, but increased considerably in 2016 with 403 captures and 3.33 ABB per trap night. Capture rates in 2017 were about half of those in 2016 with 226 captures and 1.77 ABB per trap night (Dr. Dan Howard and C. Hall New Hampshire University, pers. comm. 2017).

Other portions of the Flint Hills Analysis Area in Osage County and northern Washington County in Oklahoma and Chautauqua and Montgomery Counties in Kansas, have documented ABB presence, but these surveys were not designed to estimate population densities. ABB surveys have documented the presence of ABBs at several ODWC Wildlife Management Areas (WMAs) in the Flint Hills Analysis Area, including the Osage (Western Wall and Rock Creek Units), Hulah, and Copan WMAs in recent years. Relatively few recent surveys have been conducted in Kansas and the status of ABBs in that state is uncertain.

Loess Canyons

The Nebraska Loess Hills population was thought to be declining in 2006 and 2007, but that short-term decline was likely caused by the effects of drought on carrion availability (W. Hoback, University of Nebraska, pers. comm., March 24, 2011) and the population there has increased in recent years with relief from the drought. This population has a higher risk of extirpation due to its sensitivity to droughts, habitat impacts from eastern red cedar expansion, relatively small size and isolation from other populations (W. Hoback, Oklahoma State University, pers. comm., August 31, 2017).

Sandhills

Based on trapping efforts more recently in the Nebraska Sandhills, many more ABBs occur in that population than previously recognized. In 2010, more than 1,000 ABBs were trapped in Nebraska with relatively limited trapping. This analysis area has the highest ratio of positive to negative surveys, See Figure 4-12 for the last 15 time frame, and Table 4-3.

Niobrara River

The South Dakota population – The South Dakota population ,with a focus on Tripp County, has been surveyed/monitored from 1995 to 2009 by Gary Marrone and Doug Backlund. In 2005 they conducted a mark re-capture population estimate study, where relatively little change in abundance was documented since 1995. The highest catch per trap night rates were recorded in 2006, 2007 and 2009. However, in Todd, Gregory, and Bennett Counties South Dakota, there appear to be a single record each found in 1998, 1995, and 2007 respectively. Much less survey effort has occurred in these two counties compared to Tripp County. This is a reduction from 1995 where 41 ABBs were captured over Tripp and Gregory Counties, but not in Todd County, the westernmost survey area (Backlund and Marrone 1997, pp. 56). Other areas of South Dakota have been minimally surveyed with no ABB found.

Dr. W. Wyatt Hoback reported that the population in South Dakota was maintaining itself and capture rates were higher than those reported by Backlund et al. (2008) during the June time period because they captured 361 ABB (W. Wyatt Hoback 2014 report under Section 10 permit). Dr. Hoback also surveyed the northern section of Nebraska that year and concluded that the population there was also maintaining itself. A total of 272 ABB were caught in 2014 in northern Nebraska

During 2003, Backlund and Marrone reported that although captures of ABB were among the best they have ever recorded, a difference in distribution was observed. The dissected hills along the Keya Paha River in past years had revealed “good” presence of ABB. But in 2003, only a single ABB was captured in those habitats. All other ABB were captured in the sandy habitats to the north and east; lending further evidence to the hypothesis that the source population is tied to the sand habitats of southern Tripp County. This higher abundance is thought to be from the high water table under the sand that probably provides a more drought resistant habitat, and remains productive even in drought years, as was observed in the dry years experienced in 2002 and 2003.

In 2006, the population in Tripp County during drought years recorded abundance (catch per trap night) of teneral ABB’s; extreme heat and drought conditions was thought to cause abnormally high mortality of vertebrates; thus providing a large number of food and carrion resources for a very successful brood rearing and survival year.” (Backlund and Marrone 2003, pp. XX). In 2005, Backlund et al. (2008) conducted two mark and recapture surveys during June and August, in southern Tripp County. The population size of ABB in an area of approximately 220 km^2 was estimated to be 333–634 in June (adult population) and 714–1177 in August (adults and tenerals.). Estimates were obtained using a family of models (program CAPTURE).

<u>*New England*</u>

The sentinel population of ABBs on Block Island off the coast of Rhode Island is relatively stable with population estimates ranging from 200-1,000 (Figure 4-15). This population has been monitored annually since 1991. Carrion provisioning has been conducted on Block Island since 1993. Pairs of beetles have been placed with appropriate carrion in shallow holes and then covered by wire screening to protect them from predators. The population of ABB on Block Island probably fluctuates among years for a variety of reasons, including carrion availability, recruitment in the previous year and winter mortality. Estimates also fluctuate due to the behavior of the species and conditions during the surveys (Raithel 2016, unpublished report to the U.S. Fish and Wildlife Service).

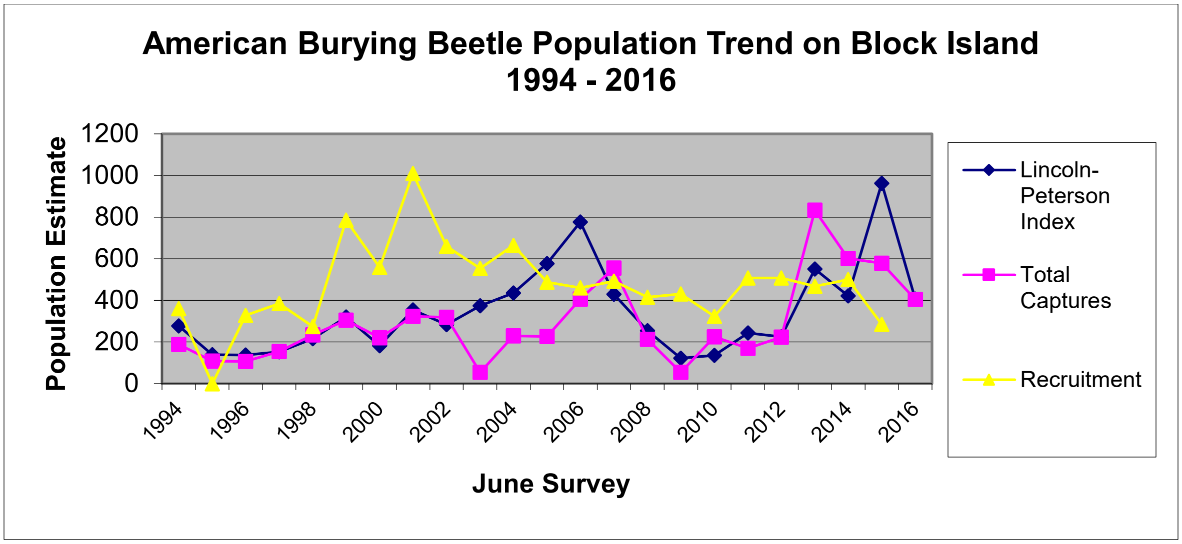


Figure 4-15 Population trend of American burying beetles on Block Island, RI from 1994 to 2016 including measures of total captures, recruitment, and estimated population size based on the Lincoln-Peterson Index.

Nantucket Island - Since 1993 multiple organizations have collaborated to reintroduce ABBs to Nantucket Island, Massachusetts, USA. The following information is provided in Mckenna-Foster et al. 2016 (entire). "Reintroduction methods were successful, but the reintroduced population does not appear to be self-sustaining and requires human assistance for long term maintenance. After provisioning was reduced in 2011, the density has decreased each year. The number of ABBs captured each summer is significantly and positively correlated with the number of broods provisioned the previous year [linear regression, R2=0.85, F(1,7)=39.7, p=0.0004]. The authors suggest that a lack of appropriate sized natural carrion is the main reason for this decline."

4.5 REINTRODUCTION AREAS AND EXPERIMENTAL POPULATIONS

4.5.1 New England Population

Attempts to reintroduce the ABB have occurred on Penikese Island, MA (Amaral et al. 1997) and Nantucket Island, MA (Mckenna-Foster et al. 2015). The first reintroduction site for the ABB was Penikese Island, Massachusetts in 1990. ABBs were released on Penikese each of four years, from 1990 to 1993. Based on follow-up surveys, a population persisted there for about eight years (until 2002). No ABBs were subsequently found there during modest trapping efforts from 2003 to 2006. Information on the Nantucket Island population is provided with the New England Analysis Area population information above.

4.5.2 Missouri Experimental Population

The Service has established Missouri as a non-essential experimental population location in accordance with section 10(j) of the Endangered Species Act prior to the release of the ABBs. The Saint Louis Zoo in cooperation with The Nature Conservancy (TNC) in 2011 began an effort to reintroduce ABB to the Wah'kon-tah Prairie; a 3,030 acre site jointly owned and managed by Missouri Department of Conservation (MDC) and The Nature Conservancy (TNC). Wah'kon-tah prairie straddles the border of St. Clair and Cedar counties, and is very close to Bates and Vernon counties. These four counties, measuring 2,885 square miles, serve as the boundary of the experimental population. More specifically, three centrally located areas were used as reintroduction sites. Brood stock is provided by Fort Chaffee, Arkansas to the Saint Louis Zoo where they are reared, paired and provisioned for reintroduction in Missouri.

The 2015 effort marked the fourth year of this reintroduction, with 152 pairs of captive bred beetles (one male and one female) released at three different locations on the prairie. There were 172 pairs of beetles released in 2014, 302 pairs released in 2013, and 148 pairs released in 2012. Before being released, all beetles were notched on their elytra with a cauterizing tool to distinguish them from any beetles produced on the prairie. The following spring after the 2012 reintroduction, a single un-notched ABB was captured indicating recruitment and overwintering success on site. In 2013, 15 un-notched ABBs were collected and in 2014, captured 36 un-notched ABBs. A total of 93 ABBs were collected on Wah' Kon-Tah Prairie in 2015 after the reintroduction. Seventy-three (73) of the collected ABB (including those collected before the reintroductions) were un-marked and 20 were marked recaptures. By the end of August, 2016, 685 ABBs were captured and 368 were un-marked. This high number of un-marked captures indicates this Missouri reintroduced 10(j) experimental population seems to be showing signs of establishing a self-sustaining population. In 2017 ABB numbers were lower. A total effort of 972 trap nights at Wah' KonTah and surrounding sites were conducted between May 24 th and September 21 st , 2017. Zoo staff captured a total of 207 Nicrophorus americanus in 2017, and a total of 143 of these were un-notched beetles. 36 Nicrophorus americanus were collected on Wah' Kon-Tah before the reintroduction in June. These beetles had no notches on their elytra or pronota, indicating that they had not been released during the previous year's reintroduction, nor had they been captured at any point during the previous year. Also a total of 74 un-notched beetles were captured either in regular trapping or in the MDC Mark/Recapture blitz prior to July 16th. These beetles, combined with the two overwintering beetles found during the early 2014 season, and the nine overwintering beetles found early in the 2015 season, and seventeen overwintering beetles found early in the 2016 season provide strong evidence that American burying beetles released on Wah' Kon-Tah Prairie are successfully reproducing and overwintering. • A total of 426 N. americanus were released during the reintroductions. A total of 143 N. americanus without any notches were captured in Zoo traps during the 2017 survey season (a total of both pre- and post-release) and.75 total N. americanus (including 43 unmarked beetles) were captured during the two MDC mark/recapture blitzes. These beetles bring the total of unmarked beetles captured for the 2017 season to 186 N. americanus. Since this total number factors in the individuals caught in the Zoo line traps during the two Mark/Recapture events, it is the true total of unmarked beetles for the 2017 season. The lack of notching indicates that these beetles were produced in the wild. Re-sampling at Wah' Kon-Tah Prairie over several years has demonstrated that the number of individuals of a species varies from year to year, but that the number of species at the site remains constant. Factors such as changes in weather patterns, land usage, and changes in the number of competing species can affect the number of individuals at a site. There were a total of nine N. americanus captures at nearby Monegaw Prairie C.A. Seven of the nine were unmarked beetles and two were recaptures. Additional time and monitoring will provide more assurances that this population will sustain itself without assistance.

4.5.3 Ohio Reintroduction Sites

The Cincinnati Zoo and The Wilds both help propagate ABBs for release at Fernald Preserve (Butler and Hamilton counties) and The Wilds (Muskingum County.) Previous releases at the Wayne National Forest were unsuccessful. Prior to 2014 all of the wild-caught founder ABBs were donated from Ft. Chaffee, Arkansas and propagated with cooperation from the St. Louis Zoo. In 2014, the founder ABBs were from Nebraska. Each ABB was paired with a mate and provided with a carcass as a head-start, and although breeding success has been documented each year from the reared ABBs, no overwinter survival has been documented through the post-release monitoring the following spring.

Experts, both working on the ground and within the Service agree that the latitude of the reintroduction could be influencing the ABBs' ability to adapt to the varying climate regime from their original location. Ohio has harder freezes, a longer winter, and a shorter active season than Arkansas, which could influence ABB's habits enough to cause death during overwintering. Therefore in 2013, to compensate for the potential adaptation issue, the group determined the best approach would be to use founder ABBs from a northern latitude such as Nebraska, and since Nebraska and Ohio are similar latitudes, ABBs were obtained and propagated from Nebraska in hopes that founders from the northern population would be more suitable for reintroduction into Ohio, allowing for overwinter survivorship. The 2014 Ohio releases were the progeny of the Nebraska ABBs, however, still no overwintering survival has been documented. We are unsure if overwinter survivorship is not happening or if survivorship is simply too low for detection in spring pre-release monitoring. We are continuing to explore factors for why no overwintering is being documented for this population.

4.6 CURRENT CLIMATE

According to NASA, global mean temperature has risen 1.7°F since 1880, with much of the change occurring since 1970 (Figure 4-16, climate.nasa.gov, accessed October 20, 2016). Temperatures in the contiguous U.S. have risen by a similar amount during the same period. Precipitation intensity has also increased, especially across the Midwest and Northeast U.S. (Walsh et al. 2014, Chapter 2 entire).

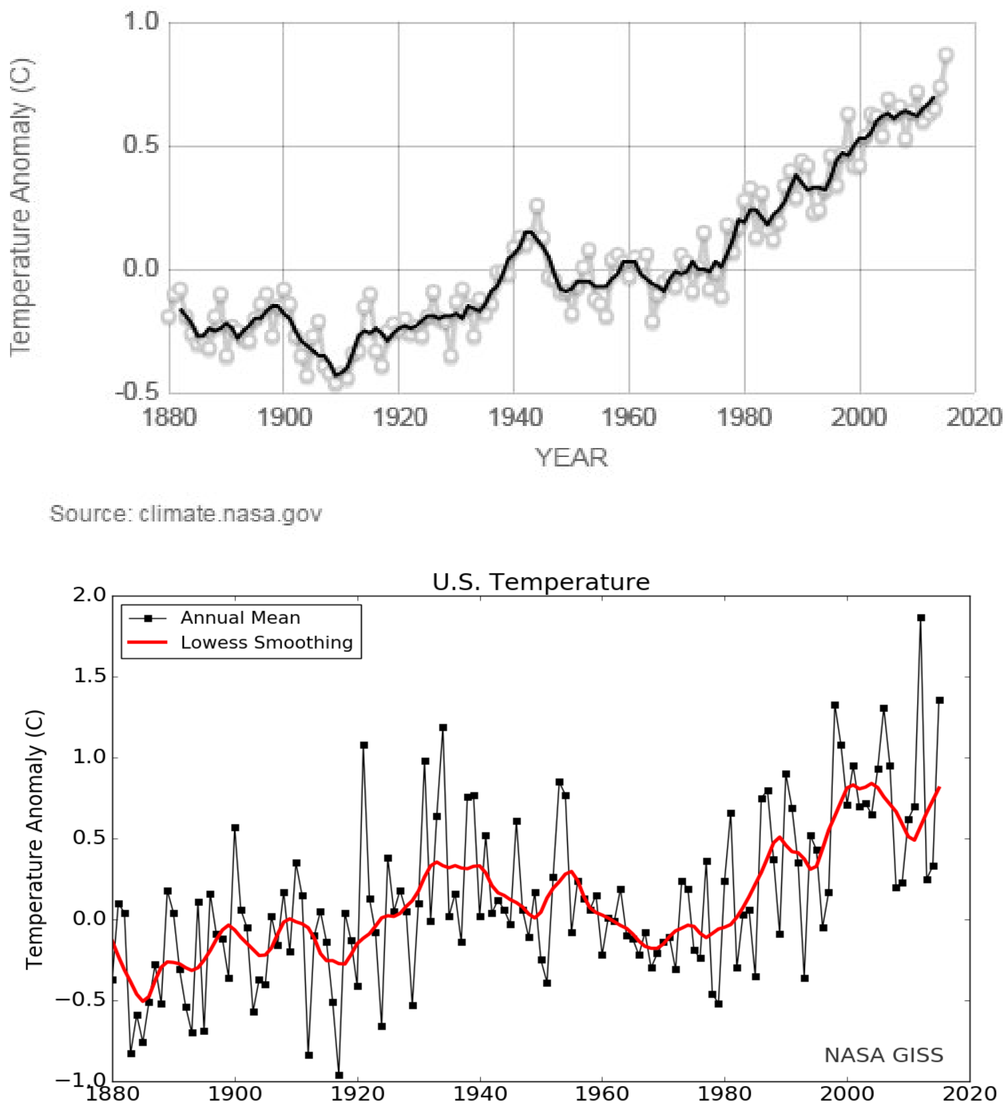


Figure 4-16. Global Temperature Anomaly (Top, change in temperature relative to the 1951-1980 mean) from 1880 to present. Bottom, U.S. Temperature Anomaly, also from 1880 to present.

4.6.1 Known ABB Biological Limitations Related to Temperature

Climate has always limited the ABB range and current populations to some degree. Populations at the northern edge are limited by cool night time temperatures and shorter growing seasons (see ABB temperature discussion in section 2.4.1). The western edge has likely been limited by a combination of temperatures and reduced precipitation or soil moisture. The ABB population at the southern edge of its range is likely limited by high temperatures (see section 3.8.2 and 4.4.2 for additional related discussion). While data is lacking for direct evidence that implicates a changing climate may be limiting the distribution of some ABB populations/metapopulations, there is anecdotal information that indicates this may already be occurring in the southern and western terminus of its range.

The effects of drought and deluge have short-term observable effects to ABB populations. However, losses associated with one-time or short-duration pulse are less likely to affect overall population survival than longer-duration weather to climate-related adverse effects. Drought conditions appear to reduce ABB catch rates in both the northern and southern plains analysis areas and extended droughts due to climate change could make portions of the current ABB range unsuitable during those droughts.

Although we do not have precise upper and lower temperature thresholds for ABBs, there is evidence that reproductive activity may be limited when air temperatures are above 77° F or below 60° F. Likewise, mortality of individuals has been documented when air temperatures exceed 90° F. After a cooling system failure at the St. Louis Zoo, temperatures of an ABB captive colony reached 85-90° F all day for about 2 weeks. Some mortality occurred and all surviving ABBs were subsequently unable to successfully reproduce (Bob Merz personal comm. September 2016). Curtis Creighton (personal comm. July 2016) provided information from recent temperature studies (constant temperatures in a laboratory with air and soil temperatures the same) with *N. orbicollis* that indicates even small changes in air and soil temperature can affect reproduction. The percent of successful broods declined at air temperatures greater than 68° F and declined rapidly at any temperatures greater than 77° F. An increase of only 4-5 degrees (from 77.0° to 80.6-82.4° F) stopped most beetles from attempting to prepare a carcass for reproduction and those that did were not successful in producing any larvae or pupae. Similar results occurred at low air temperatures. The percent of successful *N. orbicollis* broods declined at temperatures less than 68° F and declined rapidly at any temperatures less than 59° F. A decrease of only 4 degrees (from 59.0° to 53.6-55.4° F) stopped most beetles from attempting to prepare a carcass for reproduction and those that did were not successful. Temperatures for ABB reproduction are likely to be similar to *N. orbicollis*. They are the most similar congeners in North America; both species are nocturnal (although *N. orbicollis* can be active at dusk and dawn) and have very similar historic ranges. In their actual habitat, air and soil temperatures can be different and far more variable, but soil temperatures can exceed 80° F at 10 inches of depth by July in most years in southern Oklahoma (Oklahoma Mesonet data). The decision to bury a carcass would likely be based on the air temperature when the carcass was found, but decomposition rates of buried carcasses and successful development of eggs and larvae would be based on soil temperatures.

Additionally, ABBs become active at night when temperatures are above 55-60°F. Below 55-60°F, ABBs are rarely captured in traps and may be incapable of efficient flight. This would inhibit finding carrion and foraging. Finding carrion for feeding is important during the active season and could be important during the fall to store energy needed to survive a winter. *N. orbicollis* observed overwintering in Nebraska were found to position themselves near the frostline, indicating a metabolic advantage, like aestivation, occurring near freezing ground temperatures (Conley 2014; pp. 49). The colder temperatures became, the deeper beetles would bury, and the warmer temperatures became, the shallower beetles would bury. This indicates beetles base their burial depth on temperature and avoided freezing temperatures and beetles that overwinter slow their metabolic processes to survive. There was no difference in over-winter survival rates of beetles that had access to a carcass and those that did not. They were able to stay the duration of the winter in soil below the frost line and did not need food provisions that beetles in above freezing temperatures utilize for survival (Conley 2014; pp. 35–68). In contrast, Schnell *et al.* (2008, p. 483) found that ABBs that were provided a carcass had a higher survival rate (77.1% and 44.6% survival in provisioned and nonprovisioned buckets, respectively) in an over-wintering study in Arkansas (no frostline), that indicates access to food could be important when winter temperatures are above freezing. Warmer temperatures in the winter may not slow the beetle's metabolic process enough to aestivate and may affect the beetle's ability to survive a winter without access to food. Finding new sources of food could be difficult if temperatures were not warm enough for flight.

4.6.2 Current Effects of Temperature on ABB

It is for the reasons discussed in 4.6.1 above that two metrics of historical climate change were chosen for our current condition temperature analysis. Those metrics were nights per year with temperatures above 75°F (high temperatures with likely reduced or no reproduction) and nights per year between 32°F and 60°F (likely metabolically stressful with no aestivation and limited foraging). Temperature data were collected from recent historical records (1981 – present) found for selected locations using PRISM Gridded Climate Data (PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 4 Feb 2004). Information about how the PRISM dataset is calculated and weather stations used in the model can be found at http://prism.oregonstate.edu/documents/PRISM_datasets.pdf. Data for the current year (2016) were omitted because complete and verified data were not available at the time of analysis. Data were collected from locations in each analysis area near the eastern and western border of that analysis area (Table 4-4). After the number of days for each year analyzed for each metric was calculated, those time-series for each location were explored using t-test and natural log linear regression (Year was used to predict the natural log + 1 transformed day count). T-tests were one tailed (an increase in days was hypothesized), assumed unequal variance, and explored the difference between the first 17 years of analysis (1981 to 1997) and the last 17 years of analysis (1999 to 2015). No trends or significant differences were observed for the metric measuring the number of nights between 32°F and 60°F for any analysis area. Nights above 75°F were only observed in the southern analysis areas (Red River, Arkansas River, and Flint Hills analysis areas) with the exception of seven nights over 35 years in Colome, SD (1 night in 2001, 3 nights in 2006, and 3 nights in 2011). All calculations and statistical analyses were performed using Microsoft Excel 2010 (Redmond, WA).

Table 4-4. Names and locations of sampling points for extraction of temperature time-series from PRISM Gridded Climate Data.

Analysis Area Nearest Town	Side of Analysis Area	Latitude	Longitude
Red River			
Idabell, OK	East	33.8768	-94.7997
Hugo, OK	West	34.0090	-95.5391
Arkansas River			
Van Buren, AR	East	35.4103	-94.3335
Shawnee, OK	West	35.3745	-97.0014
Flint Hills			
Freedonia, KS	East	37.5368	-95.8321
Webb City, OK	West	36.7959	-96.7033
Loess Canyons			
Lexington, NE	East	40.7587	-99.7786
Wellfleet, NE	West	40.7447	-100.7329
Sand Hills			
Amelia, NE	East	42.2168	-98.9120
Thedford, NE	West	41.9954	-100.5887
Niobrara			
Colome, SD	East	43.2582	-99.7019
Merriman, NE	West	42.9172	-101.7023

The number of nights with temperatures harmful to ABB reproduction increased in all southern analysis areas (Figure 4-17). This increase appeared to be most consistent after 1995 through the present. The Arkansas River analysis area experienced the greatest increase in stressful nights, but all locations in the southern analysis areas experienced significantly more stressful nights between 1999 and 2015 compared to 1981 to 1997 (Table 4-5). This increase in stressful nights was also evident as a significant trend, represented by linear regressions in all locations except Idabell, OK (Red River analysis area).

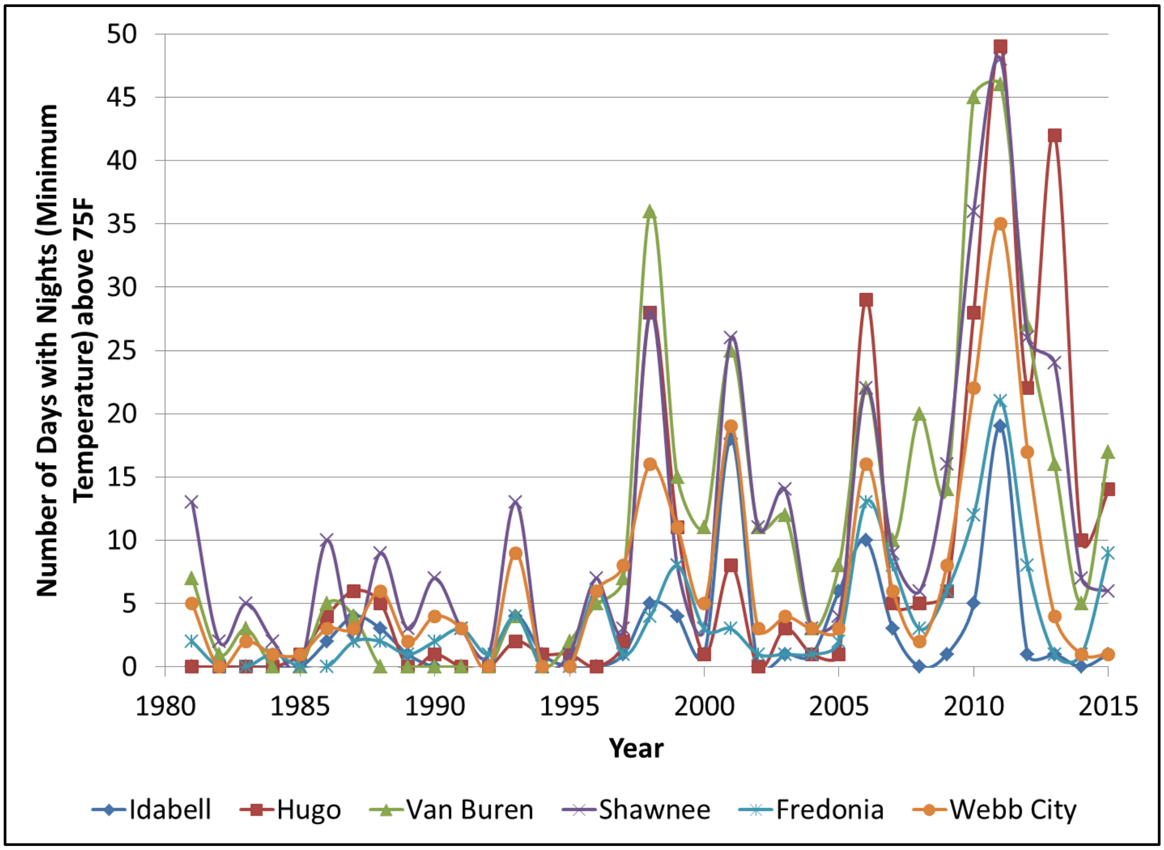


Figure 4-17. Plot of the number of days per year with nights (minimum temperatures) above 75°F. Each south analysis area is represented by two cities on the east and west side of the analysis area. Idabell, OK (East) and H OK (West) are in the Red River analysis area. Van Buren, AR (East) and Shawnee, OK (West) are in the Arkan River analysis area. Fredonia, KS (East) and Webb City, OK (West) are in the Flint Hills analysis area.

Table 4-5. Results of analyses on the number of nights (minimum temperature) above 75°F per year. T-tests (one-tailed, assuming unequal variance) evaluated the difference between the first 17 years (1981-1997) and the last 17 years (1999-2015) of the 35 year time-series. Natural Log

Linear Regressions were used to develop relationships between year and number of nights with minimum temperatures above 75°F.

Analysis Area	Mean			t-test	Natural Log Linear Regression			
Nearest Town	All	Initial 17d	Final 17d	*P*-value	Intercept	Coefficient	R-squared	*P*-value
Red River								
Idabell, OK	2.66	0.94	4.24	0.0081	*Not Significant*			
Hugo, OK	8.17	1.35	13.82	< 0.0001	-166.70	0.0841	0.4721	< 0.0001
Arkansas River								
Van Buren, AR	10.89	2.24	18.06	< 0.0001	-171.86	0.0869	0.5035	< 0.0001
Shawnee, OK	10.80	4.76	15.82	0.0002	-96.84	0.0495	0.2674	0.0015
Flint Hills								
Freedonia, KS	3.71	1.47	5.94	0.0004	-95.50	0.0484	0.3441	0.0002
Webb City, OK	6.54	3.12	9.41	0.0033	-69.27	0.0355	0.1501	0.0215

The effects of the increase in nights above 75°F and potential impacts to reproductive success (described in section 3.8.2 and likely combined with other factors) may be occurring in the Red River Analysis Area where declines in positive ABB surveys have been documented since the early 2000s (see a more complete discussion in section 4.4.2). We do not have data specifically related to reproductive success in the Red River Analysis Area, but the population declines coincide with the increase in nights above 75°F and more extreme fluctuations in climate since 1997. The Red River Analysis Area formerly (1993-1996) supported at least local areas with good ABB catch rates in the southeastern portion (Creighton et al. 2009, page 40), but positive/negative ratios and catch rates have declined since the early 2000s. No positive surveys have been documented in the Arkansas or Texas portions since 2008 and only a few positive surveys are known in the Oklahoma portion since 2006. Populations in TX may be extirpated. A more complete discussion of potential climate effects is provided in Chapter 3, section 3.8.2 and future effects in Chapter 5, section 5.4. A more detailed description of the Red River Analysis Area population status and recent trends is in section 4.4.2.

4.7 CURRENT RESILIENCY, REPRESENTATION, AND REDUNDANCY

4.7.1 Current Resiliency

Resiliency describes the ability of a population to withstand either periodic or stochastic disturbance events, not rising to the level of catastrophic. Resiliency is positively related to population size and growth rate and may be influenced by connectivity among populations. Generally speaking, populations need abundant individuals within habitat patches of adequate area and quality to maintain survival and reproduction in spite of disturbance. For the purposes of this report and the SSA process, the term resiliency is applied to analysis areas (or populations) and is not used for the species or the entire range. The term viability is used for the species as a whole.

To summarize the overall current condition of ABBs in analysis areas, we designated three relative categories (good, fair, and poor) based on the population and habitat factors (Table 4-6). The current condition category is a qualitative estimate based on the analysis of the three population factors - relative abundance, population distribution, and known trend and two habitat elements – availability of suitable ABB habitat and amount of protected areas for the ABB, including the level of management of those protected areas.

Table 4-6. Habitat and Population Condition Category Definitions

	Population Factors			**Habitat Factors**	
Condition Category	**Relative Abundance**	**Population Distribution**	**Known Trends**	**Available Habitat**	**Protected Areas and Management**
Good	Good - Positive to negative survey ratios >40%…..	Good – Presence recently documented throughout the analysis area with large concentrations that are interconnected	Good – Most monitored sites indicate increasing or relatively high catch rates or ratios of positive to negative surveys	Good-Total suitable habitat area is large (>2,000,000 acres) and > 1,000,000 acres of favorable habitat	Good- More than 200,000 acres of combined managed and multi-use protected lands
Fair	Fair - Positive to negative survey ratios >25%…..	Fair – Presence recently documented within at least half of the analysis area with at least one large concentration or all concentrations interconnected	Fair – Monitored sites indicate fluctuating catch rates or ratios over time with repeated recoveries	Fair- Total suitable habitat area is moderate-large >1,000,000 acres	Fair- More than 100,000 acres of combined managed and multi-use protected lands
Poor	Poor - Positive to negative survey ratios <25%…..	Poor – Presence recently documented in less than half of the analysis area and no large concentrations or the concentration is isolated	Poor – Most monitored sites indicate declining catch rates or ratios	Poor- Total suitable habitat is <1,000,000 acres	Poor- Less than 100,000 acres of combined managed and multi-use protected lands
Ø	-	-	-	-	-

Because we have limited information by which to measure population resiliency based on actual population estimates, the primary indicators of resiliency are area and condition of habitat, geographic distribution of ABBs within analysis areas, relative abundance (based on ratios of positive to negative surveys), and size and number of concentrations of positive surveys within an analysis area.

For this report, resiliency is classified as high, moderate, or low for each analysis area. High resiliency represents a combination of population and habitat factors that are good to fair and would support a high probability of maintaining populations and withstanding periodic or stochastic disturbances under current conditions. Moderate represents a combination of population and habitat factors that are mostly good to fair, but may have some reduced resiliency due to factors classified as poor, and would support a moderate probability of maintaining populations (and withstanding periodic or stochastic disturbances) under current conditions. Low resiliency represents a combination of population and habitat factors that are mostly fair to poor (but may have some factors classified as good) and would only support a low probability of maintaining populations and withstanding periodic or stochastic disturbances under current conditions.

Red River Analysis Area

Suitable habitat- Good –The 2,678,406 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4.1) is relatively large, but conditional habitat is 37% of the total area and about half of the suitable acres which makes it relatively sensitive to changes in land uses. The suitable area is relatively small compared to other analysis areas.
Protected Areas- Fair- There are 123,779 acres of managed and 23,997 acres of multi-purpose protected lands. Protected areas include Department of Defense, U.S. Forest Service, USFWS National Wildlife Refuge, and ODWC wildlife management area lands. Only the Hugo Wildlife Management Area (Corps land Managed by ODWC) is currently known to support ABBs with 5 ABBs captured in 2016 (see Table 4-2 Protected Lands).

Distribution within the Analysis Area - Currently the distribution is poor with only a few positive surveys in the northwestern and southcentral portion of the analysis area. Expanding the timeframe to the last 15 years of surveys improves the distribution, and that data indicates one area of concentrated positive surveys in the southeast corner, 7 positives in the central and 4 positives in the western portion. However, the concentration of positive surveys in the southeast corner has not been sustained and there are relatively few positive surveys since 2008 in any portion of this analysis area. The kriging interpolation in Figure 4-13, illustrates the distribution and likelihood of ABB presence within the analysis area (see Appendix A for more information on the kriging methods).

Relative Abundance - Ratio of Positive to Negative Surveys - This analysis area has poor relative abundance. The analysis area has a low ratio of positive to negative surveys with only one area of concentrated positive surveys in the last 15 years and no concentrations in the last 10 years. See Table 4-3 and Figure 4-13 for the last 15 and 10 year time frames.

Summary - The Red River Analysis Area includes 3,251,894 total acres in portions of Arkansas, Texas and Southeastern Oklahoma near the Red River (fig 4-12). The Red River Analysis Area formerly (1993-1996) supported at least local areas with good ABB catch rates in the southeastern portion (Creighton et al. 2009, page 40), but positive/negative ratios and catch rates have declined since the early 2000s. No positive surveys have been documented in the Arkansas or Texas portions since 2008 and only 8 positive surveys are known (all in Oklahoma) since 2008. Populations in TX may be extirpated. The current resiliency of the Red River Analysis Area is considered low due to the limited distribution and very low ratios of positive to negative surveys in recent years.

Arkansas River Analysis Area

Suitable habitat- Good- There are 14,470,603 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1). This is a large area relative to other analysis areas.

Protected Areas – Good- There are 1,486,002 acres of managed and 933,608 acres of multi-purpose protected lands. Protected areas include multiple federal, state and private areas and many are known to support ABBs, (see Table 4-2 Protected Lands).

Distribution within the Analysis Area - Currently good with some positive surveys in all portions of the analysis area and scattered concentrations of positive surveys in all but the northeastern portion. The areas of concentrated positive surveys are not contiguous and may illustrate areas of habitat fragmentation, but most of the concentrated areas are not widely separated (see Figure 4-12). The kriging interpolation in Figure 4-12, illustrates the distribution and likelihood of ABB presence within the analysis area (see Appendix A for more information on the kriging methods).

Relative Abundance - Ratio of Positive to Negative Surveys- Fair- This analysis area has a fair ratio of positive to negative surveys with several areas of concentrated positive surveys in the last 15 years. See Figure 4-12 for the last 15 year time frame, and Table 4-3.

Summary- The Arkansas River Analysis Area includes 17,753,431 total acres in portions of Arkansas, Oklahoma and Kansas. The current resiliency of the analysis area is considered high due to the large area, good distribution, several large protected areas, and fair ratios of positive to negative surveys (compared to other analysis areas, see Table 4-3).

Flint Hills Analysis Area

Suitable habitat - Good- There are 2,846,079 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1). This is a small-medium sized area relative to other analysis areas.

Protected Areas - Good- There are 133,196 acres of managed and 52,114 acres of multi-purpose protected lands. Protected areas include federal, state, tribal and private areas and many are known to support ABBs, (see Table 4-2 Protected Lands).

Distribution within the Analysis Area - Currently fair with some recent positive surveys in the southern 2/3 of the analysis area and one concentration of positive surveys. The kriging interpolation in Figure 4-12, illustrates the distribution and likelihood of ABB presence within the analysis area (see Appendix A for Kriging methods). The survey effort in portions of this analysis area is limited (see Figure 4-12).

Relative Abundance - Ratio of Positive to Negative Surveys, Poor - This analysis area has a relatively low ratio of positive to negative surveys with relatively large fluctuations between years. Reports for 2016 indicated more positive surveys and a higher ratio of positives but some areas have limited survey effort. Portions of this analysis area have a very low ratio of positive surveys that indicates low density populations. See Figure 4-12 for the last 15 year time frame, and Table 4-3.

Summary- The Flint Hills Analysis Area includes 3,706,908 total acres in portions of Oklahoma and Kansas. The current resiliency of the analysis area is considered moderate due to the large area of native habitat, good distribution and adjacent to the Arkansas River Analysis Area, several large protected areas, and ratios of positive to negative surveys that are on average low, but can periodically be good in some locations (compared to other analysis areas, see Table 4-3).

Loess Canyons Analysis Area

Suitable Habitat – Fair- There are 2,758,610 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1), but less than 1,000,000 acres of favorable habitat. The analysis area is small relative to other analysis areas.

Protected Areas- Poor- There are only 15,342 acres of managed and 3,843 acres of multi-purpose protected lands. In addition there are 5 conservation easements, held by the Nebraska Land Trust, in the Loess Canyons, totaling 3,277 acres. Protected areas are known to support ABBs, (see Table 4-2 Protected Lands).

Distribution within the Analysis Area - Currently fair with one relatively large contiguous concentration of positive surveys in the center of the analysis area (see Figure 4-12). The kriging interpolation in Figure 4-12, illustrates the distribution and likelihood of ABB presence within the analysis area (see Appendix A for kriging methods).

Relative Abundance - Ratio of Positive to Negative Surveys- Fair- This analysis area has a fair ratio of positive to negative surveys. See Figure 4-12 for the last 15 year time frame, and Table 4-3.

Summary - The Loess Canyons Analysis Area includes 2,758,610 total acres in southcentral portions of Nebraska. The current resiliency of the analysis area is considered moderate due to the large area of native habitat, fair distribution, fair ratios of positive to negative surveys (compared to other analysis areas, see Table 4-3). However, expansion of eastern red cedar due to a lack of fire or mechanical control has reduced the habitat quality in much of this analysis area and this population is sensitive to droughts. The analysis area is relatively small and isolated from other populations.

<u>*Sandhills Analysis Area*</u>

Suitable Habitat- Good- There are 8,633,685 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1) and it is a large area relative to other analysis areas.

Protected Areas- Good- There are 393,983 acres of managed and 24,633 acres of multi-purpose protected lands. Most protected areas are known to support ABBs, (see Table 4-2 Protected Lands), but some large forested areas have relatively few positive surveys. The Valentine National Wildlife Refuge is the only large block of protected lands in this analysis area with relatively good numbers of ABBs, but smaller protected areas near the Niobrara River also have ABBs (W. Hoback, Oklahoma State University, pers. comm., January 22, 2018).

Distribution within the Analysis Area - Currently good with some positive surveys in all portions of the analysis area and one large contiguous concentration of positive surveys (see Figure 4-12). The kriging interpolation in Figure 4-12, illustrates the distribution and likelihood of ABB presence within the analysis area (see Appendix A for more information on the kriging methods).

Relative Abundance - Ratio of Positive to Negative Surveys - Good- This analysis area has the highest ratio of positive to negative surveys. See Figure 4-12 for the last 15 year time frame, and Table 4-3.

Summary - The Sandhills Analysis Area includes 10,819,170 total acres in northcentral portions of Nebraska. The current resiliency of the analysis area is considered high due to the large area of native habitat, good distribution, and good ratios of positive to negative surveys (compared to other analysis areas, see Table 4-3).

Niobrara River Analysis Area

Suitable Habitat- Good – There are 2,961,469 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1), but it is relatively small compared to other analysis areas.

Protected Areas- Poor – There are only 58,918 acres of managed, 33,582 acres of multi-purpose protected lands. It includes a large area of tribal land, but no ABBs have been documented there. Some protected areas are known to support ABBs, (see Table 4-2 Protected Lands). The two state-owned game production areas where ABB have been trapped are Dog Ear Lake and Rahn Lake. Additional state-owned land exists on the eastern edge of the Analysis Area and but no ABB surveys have been conducted there. The managed area of the national wildlife refuge has been surveyed, but no ABBs have been found.

Distribution within the Analysis Area – Currently Fair with some positive surveys in all portions of the analysis area and one contiguous concentration of positive surveys (see Figure 4-12). The kriging interpolation in Figure 4-12, illustrates the distribution and likelihood of ABB presence within the analysis area.

Relative Abundance - Ratio of Positive to Negative Surveys- Fair -This analysis area has a fair ratio of positive to negative surveys. See Figure 4-12 for the last 15 year time frame, and Table 4-3.

Summary - The Niobrara River Analysis Area includes 4,108,903 total acres in northcentral portions of Nebraska and southcentral portions of South Dakota. The current resiliency of the analysis area is considered moderate due to the good area of native habitat, fair distribution, and fair ratios of positive to negative surveys (compared to other analysis areas, see Table 4-3).

New England Analysis Area

Suitable Habitat - Poor*- There are 25,865 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1) and this is the combined total for both Block and Nantucket Islands. Block Island has 2,554 acres and Nantucket has 23,311 acres of suitable habitat. This is a small area relative to other analysis areas and is classified as poor, but the level of protection and active management partially compensates for the relatively small area.

Protected Areas - Poor*- There is a total of 14,441 total acres of protected lands. There are 2,507 acres of protected lands on Block Island and 11,934 acres on Nantucket Island. The total area of protected lands is small compared to some other analysis areas, but it is a relatively large percentage of the suitable habitat. The level of protection and active management partially compensates for the relatively small area. Protected areas are known to support ABBs, (see Table 4-2 Protected Lands).

Distribution within the Analysis Area - Currently fair with some positive surveys in most portions of the analysis area.

Relative Abundance - Ratio of Positive to Negative Surveys - This analysis area has a good ratio of positive to negative surveys on Block Island and fair to poor ratios on Nantucket Island.

Summary - The New England Analysis Area consists of two islands where ABB are known to occur: Block Island, RI and Nantucket, MA. The current resiliency of the analysis area is considered moderate due to relatively good distribution, and fair ratios of positive to negative surveys (compared to other analysis areas, see Table 4-3). The limited area of potential habitat reduces the resiliency, but the level of protection and active management with provisioning of carcasses partially compensates for the relatively small area. Block and Nantucket Islands are considered to have moderate resiliency with active management. However, Nantucket is a reintroduced population with lower ratios of positive to negative surveys and both islands are highly dependent on active management.

Resiliency Summary

Table 4-7. Summary of Factors for Current Population Resiliency

Current Resiliency						
	Habitat Factors		**Population Factors**			
Analysis Area	**Available Habitat**	**Protected Areas/ Management**	**Relative Abundance**	**Population Distribution**	**Known Trends**	**Habitat/Population Resiliency**
Niobrara River	**Good**	**Poor**	**Fair**	**Fair**	**Good**	Moderate
Sand Hills	**Good**	**Good**	**Good**	**Good**	**Good**	**High**
Loess Canyons	**Fair**	**Poor**	**Fair**	**Fair**	**Fair**	Moderate
Flint Hills	**Good**	**Good**	**Poor**	**Fair**	**Fair**	**Moderate**
Arkansas River	**Good**	**Good**	**Fair**	**Good**	**Fair**	High
Red River	**Good**	**Fair**	**Poor**	**Poor**	**Poor**	**Low**
New England	**Poor**	**Poor***	**Fair**	**Fair**	**Fair**	**Moderate***

* New England islands have less than 100,000 acres of protected lands due to the limited area of these islands, but have a relatively high percentage of conservation lands (Block, 41% and

Nantucket, 33%). Resiliency is moderate due to continued active management and provisioning of carcasses.

4.7.2 Current Representation

Representation can be measured through the breadth of genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the species' range. The more representation, or diversity, the species has, the higher it's potential of adapting to changes (natural or human caused) in its environment. Geographic distribution of occupied and potentially suitable habitat and genetic information is being used to describe representation for the ABB.

4.7.2.1 ABB Ecological Diversity

The ABB's historical and existing range includes populations from a variety of habitats and climates that could result in local or area adaptations for survival. For example, ABBs may become active as early as April in the southern part of the range and as late as May or June in northern portions. Another example is that adults (F1 generation) may potentially breed twice and their young-of-the year (F2 generation) may breed at least once within the same active season in southern populations (Red River, Arkansas River, and Flint Hills) (USFWS 1991, p. 13). ABBs reproduce only once in the northern portion of their range (Loess Canyons, Sandhills, and Niobrara River) due to the relatively short active season and the 48-65 day timeframe for reproduction (Bedick *et al*. 1999, Trumbo 2009, Scott and Traniello 1990). Additionally, western ABB populations are affected by limited precipitation/soil moisture while the population on Block Island rarely experiences similar drought conditions.

In an example of regional differences in reproductive behavior, *N. orbicollis* beetles from Oklahoma were less likely to attempt reproduction at higher temperatures, relative to individuals from Indiana or Wisconsin (Curtis Creighton personal comm. July 2016). All attempts to reproduce at the higher temperatures resulted in failures and the more southern beetles may have adapted to the warmer and more extended periods of high temperatures in the southern portion of their range. This type of research has not been conducted with ABBs, but *N. orbicollis* is the most similar congener and has a similar range.

4.7.2.2 Genetics

Earlier genetic studies found no evidence to suggest that any populations should be treated as separate, genetically independent conservation segments. Kozol *et al*. (1993, entire) examined ABB genetic variation to compare the Block Island population and the eastern Oklahoma and western Arkansas population. At that time, both populations were found to have low levels of genetic variation, and most of the variation occurred within a single population. There were no unique diagnostic bands within either population, but they found the Oklahoma-Arkansas population to be somewhat more diverse. Reduced genetic variation is often a result of founder effect, genetic drift, and inbreeding. Kozol *et al*. (1994, p. 933,) suggested, based on entire works by Waller *et al*. 1987, Lacy 1987, and Packer *et al* 1991) that multiple bottleneck events, small population size, and high levels of inbreeding may be factors contributing to the pattern of genetic variation in ABBs.

Expanding on Kozol *et al*.'s 1993 study, Szalanski (2000, enitre) compared ABB DNA from five populations: Block Island in Rhode Island, Arkansas, South Dakota, Oklahoma, and Nebraska. The authors found little evidence that the five populations had unique genetic variation, and no evidence to suggest that these five populations should be treated as separate, genetically independent conservation segments.

There is recent evidence suggesting that the New England population may represent a genetically distinct population as compared to western populations (Patricia Parker – personal communication, September 19, 2015). The University of Missouri researchers, in cooperation with the St. Louis Zoo suggest that although the two areas are distinct, they appear to share some genotypes. However, geographic isolation between the two areas will likely continue to differentiate them further, making them more distinct over time.

The researchers also examined differences between northern and southern areas, but no clear genetic distinctions were observed. However, samples did not represent all areas of the northern or southern range and samples representing additional natural populations would provide greater support for this conclusion (Rois et al, September 2015). Regarding overall genetic diversity, high genetic variability exists in both the eastern and western areas (Patricia Parker – personal communication, September 19, 2015), suggesting current genetic makeup is well adapted to changing environmental conditions.

Representation Summary

Overall representation is considered moderate. The current genetic diversity appears to be relatively high, but the ecological diversity has been reduced with the loss of about 90 percent of the historical range. The current known range does include populations from northern and southern areas and eastern and western areas of the ABB range, although representation from eastern areas is limited to the New England island populations and the genetics represented from the Block Island population.

4.7.3 Current Redundancy

Redundancy for the ABB is measured by the number of highly resilient populations of ABB within ecological regions. The number and the distribution of these populations would be important to spread out the risk and reduce the potential effects of catastrophic events. Current redundancy could range as high as 9 "populations" (including reintroduced populations),4 in the Southern Great Plains (Arkansas River, Red River, Flint Hills and a reintroduced population in Missouri), 3 in the Northern Great Plains (Niobrara, Sandhills, and Loess Canyons), and two within the New England Analysis Area (Block Island and Nantucket). We consider populations within these analysis areas to provide some form of redundancy due to separation by considerable distances, differences in habitat makeup, behavior, existing threats, land use patterns, and climate, as described above.

The large areas of potentially occupied habitat in the Northern Great Plains and southern plains analysis areas helps support the existing redundancy and resiliency for the ABB populations. However, the Red River Analysis Area has very few positive ABB surveys in recent years and the resiliency and redundancy represented by this analysis area appears to be very limited. The reintroduced population in Missouri also supports ABB redundancy in the Southern Plains area and was established with ABBs from Arkansas. The Missouri reintroduction is relatively new and currently supplemented with captive reared ABBs and carrion provisioning. It is unknown if this population could be self-sustaining, but the population has expanded rapidly and provides redundancy if maintained through natural reproduction and/or through continued provisioning and captive rearing. The New England population is widely separated from the others and is represented by two relatively small island populations. The reintroduced population on Nantucket Island does not appear to be self-sustaining (Mckenna-Foster et al. 2016) without human assistance for long term maintenance. Experimental reductions in provisioning have resulted in declining ABB numbers on the island. However, the Nantucket population has been established and sustained since 1993 and long-term plans include renewed and continued assistance through carrion provisioning and monitoring of this population.

While the redundancy could be as high as 9, a more conservative redundancy would be 5 populations (Arkansas River, Flint Hills, Sandhills, Niobrara River, and Block Island). If we only count populations that are considered self-sustaining (without human assistance), the two reintroduced populations (Missouri and Nantucket) would not be included due to questionable long-term resiliencies associated with the human assistance at these sites. The Block Island population also has human assistance in the form of carrion provisioning and the resiliency could be reduced if this assistance ceased. However, the ABB population did sustain itself prior to any assistance and we assume a reduced population may persist there without any assistance. The redundancy represented by the Red River Analysis Area currently appears to be very limited with only seven positive surveys in the last five years and long-term resiliency is so questionable that it could be discounted under a conservative scenario. The resiliency and redundancy provided by the Loess Canyons Analysis Area is also considered relatively low, because it is relatively isolated and vulnerable to redcedar expansion and extended droughts.

Redundancy Summary

The populations in the Northern Great Plains, Southern Plains and New England each provide redundancy that reduces the risk of any catastrophic events. Redundancy for ABBs may range from 5-9 depending on current status and criteria used to describe it. If one or more populations exist in southeastern areas of the ABB historical range, it would provide additional redundancy.

CHAPTER 5 – FUTURE CONDITIONS

5.1 INTRODUCTION

Primary risk factors that have potential to change the status of ABBs in the future are land use changes (conversion of grassland to cropland, high utilization of vegetation through grazing and mowing activities, and urbanization) and changing climate. Other risk factors addressed in Chapter 3 are determined or strongly influenced by land use and climate and data for these factors are not available for all analysis areas, therefore they are not individually analyzed in this chapter. For example, habitat loss, carrion availability, competition from meso-carnivores and other scavengers, pesticide use, invasive species, and even pathogens can all be influenced by land use and climate and the availability of data for these factors is limited. We used variations in land use and climate to develop scenarios for potential future conditions in each of the ABB analysis areas (Figure 5-1). Future changes in land use and climate may be different among analysis areas due to their large areas, differences in geographic location, and variety of habitats and climate conditions.

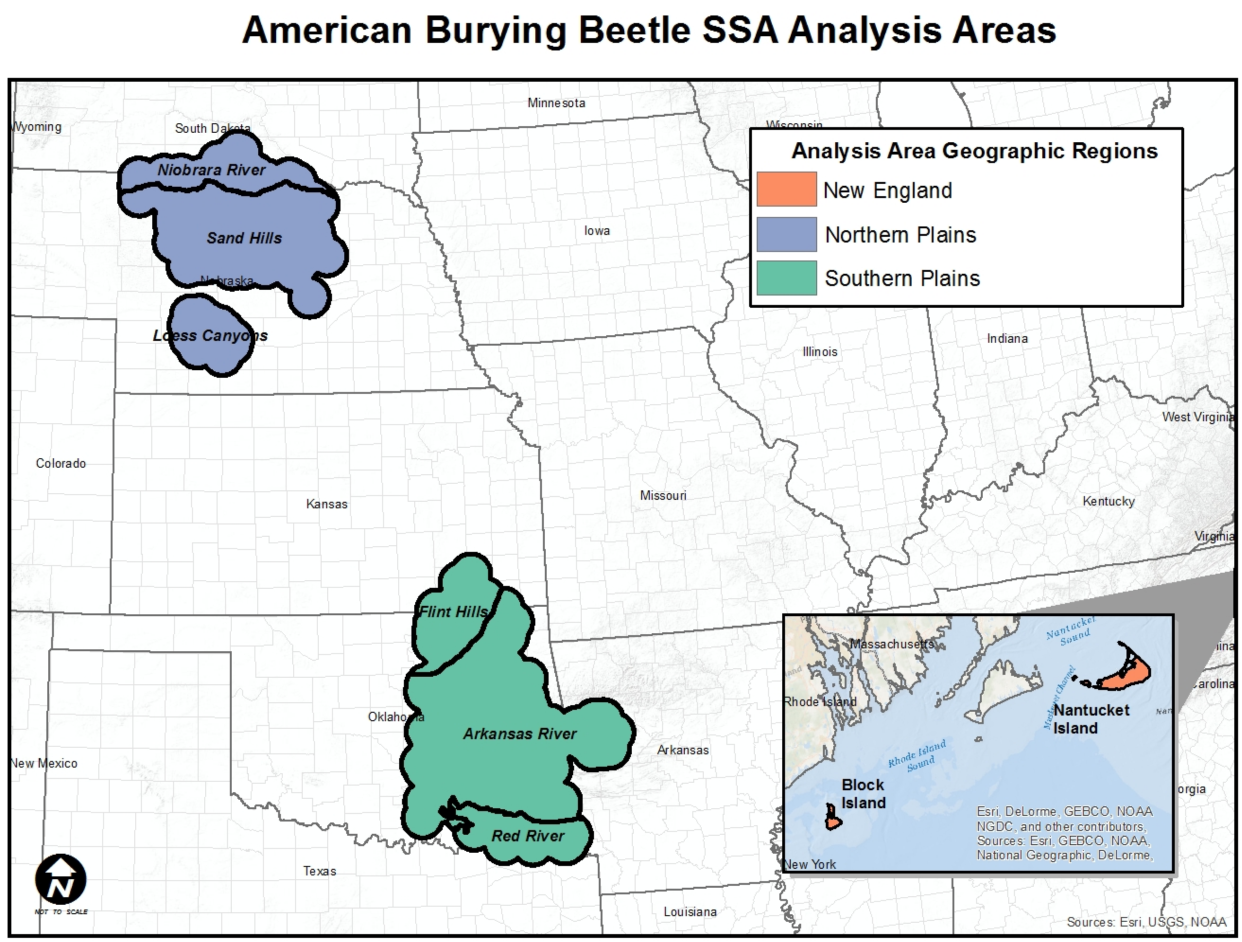


Figure 5-1. American burying beetle analysis areas grouped into three geographic regions.

In determining potential future viability, we should also consider the potential unknown or uncertain factors that led to the ABBs decline and probable extirpation of most of the eastern portion of the ABB's historical range. The potential risks that lead to the species significant geographic decline are discussed in Chapter 3 and summarized in Chapter 4 and are more thoroughly discussed in Sikes and Raithel (2002, entire). We agree with conclusions of Sikes and Raithel (2002, p.111) regarding what factors may have led to the species' decline, but uncertainty remains as to the exact causes and if those causes may be affecting current populations. Most of the eastern ABB populations were extirpated in about a 50 year period (1920-1970, although the decline likely started before then). We have not documented wide ranging declines in the ABB's existing range in the last 40 years and our known range has expanded, although this is probably due to increased survey effort. The reasons for why the decline would stop or slow are unknown; however, we have observed some declines in the Red River Analysis Area since 2005. As discussed below, evidence suggests that these recent observed declines are related to changing climate conditions in the southern extent of the occupied range, but we cannot rule out other contributing causes.

5.2 LAND USE CHANGE

5.2.1 Agriculture

Current and future conditions of ABBs are strongly influenced by anthropogenic land uses and the resulting habitat, as described by vegetation or land cover type. American burying beetles can use a wide variety of habitats that have suitable soils, temperatures and precipitation that meet their life history needs, as described in detail in Chapter 2. Anthropogenic land uses determine the condition of vegetation and habitat suitability for ABBs, the type and availability of carrion resources and of competitors. The following fits the most plausible explanation for the decline of this species–a conclusion reached first in USFWS (1991, p. 17-28) and subsequently supported and commented on by other authors (Sikes and Raithel 2002- p. 111); (1) reduction of optimally sized carrion, (2) increased vertebrate scavenger competition for that carrion, and (3) increased congener competition for optimally, and suboptimally, sized carrion–due, in part, to extinctions or declines of optimally sized prey populations resulting from habitat changes, and also to increased vertebrate scavenging and predation (Sikes and Raithel 2002, p. 111). Existing land use and the related influence on vegetation structure and composition and carrion availability appears to be the best predictor of habitat suitability for ABBs (see sections 3.2 and 4.2)

Most of the existing ABB range is in rural areas dominated by some form of agricultural use, including grazing, hay production, forestry and crop production. In some areas these agricultural land uses are being replaced with more urban (primarily residential) expansion, but the total area affected by urban expansion in most of our analysis areas is relatively minor. Agricultural uses may change in the future with changes in market conditions to more intensive agricultural uses (more intensive grazing, conversion to non-native grasses, and conversion of native vegetation to irrigated or dryland cropland) (Wright and Wimberly 2013, p. 4134).

Existing data for land covers does not give us enough detail to assess the current level or intensity of agricultural use such as grazing pressure, so land cover types like pastures and hay were combined and identified as "conditional" habitat for ABB suitability (see section 4.2). Habitat suitability for the ABB within these conditional areas will vary over time due to weather and/or intensity of agricultural uses. At any given time, some portion of conditional lands may be unfavorable habitat for ABBs.

The potential for land use changes varies within the range of the species and between analysis areas. Analysis areas in the Northern Plains (Figure 5-1) have experienced more conversion to cropland (relative to all other analysis areas) and to some extent; those types of conversions (mostly to irrigated cropland) are likely to continue into future years (Wright and Wimberly 2013, p 4134; Shafer et al. 2014, p. 447). Conversion of grassland to cropland is less likely to affect large portions of New England or Southern Plains analysis areas because crop production and row crop farming are relatively minor land uses in most of these analysis areas and a lower percentage of these analysis areas are considered suitable for row crops. Intensive grazing or mowing that maintains relatively short vegetation (less than 8 inches in height) appears to adversely affect ABB presence more in the Southern Plains analysis areas (relative to all other analysis areas) and this condition could increase in future years due to changes in climate and livestock markets. The shorter vegetation is not likely to directly affect ABBs, but is less favorable habitat for potential carrion in the southern analysis areas that would be in a preferred size range for ABB reproduction. We considered evaluating the potential change of conditional areas in the Northern Plains analysis area due to grazing pressure and related agricultural use. However, ABB survey results suggest that ABB presence within these conditional areas in the Northern Plains and New England Areas are relatively common in areas affected by grazing, at least in comparison to similar areas in the Southern Plains analysis areas. Potential carrion sources in northern analysis areas are different than in southern analysis areas and may be adapted to shorter grasslands. For example, prairie dogs and ground squirrels prefer shorter grasses and do not occur in the Southern Plains analysis areas. Additionally, sandy soils in the Northern Plains analysis areas may not be as affected by grazing-related soil compaction that can occur in soils in the Southern Plains which typically consist of more clay. Therefore, we are not including changes to conditional areas from grazing pressure in our analysis of the Northern Plains analysis areas. The effects of grazing and the differences between Northern and Southern Plains analysis areas are also discussed in Chapter 3, section 3.1.

5.2.1.1 Northern Plains Analysis Areas

For agricultural land use changes, we are assessing two possible scenarios for future conditions; a continuation of current trends (current rate scenario) and a higher rate of land use change (accelerated rate scenario), which is based on relatively recent observed increases within portions of the Northern Plains analysis areas (Wright and Wimberly 2013, p 4134). We applied a 5% net increase in cropland for our low scenario and a 30% net increase for our high scenario. These rates represent a range of conversions that have occurred in portions of the analysis areas in the last 60 years (https://www.ers.usda.gov/data-products/major-land-uses/major-land-uses/#Cropland). Other sources of historical land use changes (such as USGS land use trends from 1973-2000) were reviewed, but most provided similar rates of change, covered more of a regional area, and covered a much shorter time period. The USDA data was available down to a county level and for a longer time period. Because rate of change and timing are not possible to project (due to market variability), for the purposes of our analysis we assumed that the 5% and 30% net increases could occur anytime through year 2099. Most of the land use changes are assumed to occur by 2069 and then very low rates of change through 2099. Most lands that are feasible for conversion to cropland (grasslands and pasture with adequate soils and slope) would be converted first with remaining lands such as grassland/pasture with poor soils or steeper slopes may become cropland at a slower rate and after more feasible areas have been exhausted. Conversion of these more marginal lands is only attractive or economical under very favorable market conditions, which is difficult to project, but of which examples of such scenarios have been observed in the past (Wright and Wimberly 2013, p 4134).

5.2.1.2 Southern Plains Analysis Areas

For our analysis of the Southern Plains analysis areas, future increases in croplands is considered less likely, but higher crop prices could trigger some conversion of pasture or hayfields to cropland. Cropland has declined or had minor increases in recent years and is a relatively small percentage of southern analysis areas (see section 4.2 for descriptions of land covers in analysis areas) (Nickerson et al 2011, p 9).

Cropland is a dominant land cover in some areas with appropriate soils and is a common land cover in large river floodplains, but potential for large scale increases in cropland is limited in most of the southern analysis areas due to a predominance of soils and slopes that do not favor intensive row crop agriculture. Most of the Southern Plains analysis areas are in some form of agricultural use, but relative to the Northern Plains, a lower percentage is cropland and a larger percentage of land uses are related to forestry, pasture or hay. Therefore, we assume this pattern will continue and used a relatively low (2%) net increase in cropland for our status quo current rate scenario and a 5% net increase for our accelerated scenario, out to the year 2099. Because most of the southern analysis areas do not contain much prime farmland, most lands with good suitability for cropland have already been converted. A 2% increase would represent a reasonable estimate of potential additional conversion to cropland in most of the southern analysis areas, based on United States Department of Agriculture Economic Research Service (USDA) data for counties in recent years and within the analysis area over the last 60 years (USDA 2007). Other sources of historical land use changes (such as USGS land use trends from 1973-2000) were reviewed, but most provided similar rates of change, covered more of a regional area, and covered a much shorter time period. The USDA data was available down to a county level and for a longer time period.

Most counties within the analysis areas have lost farmland in recent years (since 1997), but some show minor increases of 2-3% in Oklahoma, and larger increases in Arkansas (4-23%) (USDA 2012, https://www.agcensus.usda.gov/Publications/2012/Online_Resources/County_Profiles/.) Within these counties, about 10-30% is cropland (with the exception of 2 counties in Kansas with about 50% cropland). We assume this could change with market conditions, but is unlikely to increase more than recent (last 20 years) total increases in farmland, which has been less than 3% in most counties. The statewide trends demonstrate changes in cropland over time, but may not reflect changes in the Southern Plains analysis areas because the analysis areas are not in portions of the states that are dominated by cropland. Conversions to cropland within the analysis areas tend to be at lower rates than in areas dominated by cropland (based on USDA county records). We assumed the high scenario for cropland expansion could be net change of 5% by 2099 which is about twice the increase in recent years and half the highest statewide rate for Oklahoma (about 10 %) during the previous 60 years. United States Department of Agriculture Economic Research Service major land use data 1945-2007 indicates statewide cropland acreage has fluctuated in Oklahoma and Arkansas with relatively minor increases and decreases during that time period. Since 1945 there was about a 10% increase by 1997, but then a 10% or greater decline by 2007 in Oklahoma. Total cropland has actually decreased in Oklahoma since 1945 and in more recent years (since 1997), but market conditions could change incentives for conversions to cropland and we have included potential increases to be conservative about considering potential land use changes.

In addition to the more permanent losses related to agricultural conversions, assumptions for the effects of temporary agricultural impacts like high utilization of vegetation via grazing or mowing for hay during drought conditions, are discussed for each Southern Plains Analysis Area. For these temporary effects we assumed a potential 30% reduction in conditional habitat for a low rate and a 60% reduction in conditional habitat as a high rate.

5.2.1.3 New England Analysis Areas

Agricultural uses are mostly pastureland and are considered suitable habitat for ABBs on the New England ABB islands. The New England islands are similar to the Northern Plains in that

ABB catch rates are relatively good in pasturelands and we assume the Block Island pasturelands support carrion sources that are suitable for ABB reproduction. Block Island supported ABBs without any assistance through carcass provisioning, both before and after the demise of nearby mainland populations by 1930. However, the current New England populations may be reliant on some level of provisioning. Cropland is not considered suitable habitat, but there are very limited areas of cropland on the islands and no additional conversion of grassland to cropland is expected (Figure 5-2).

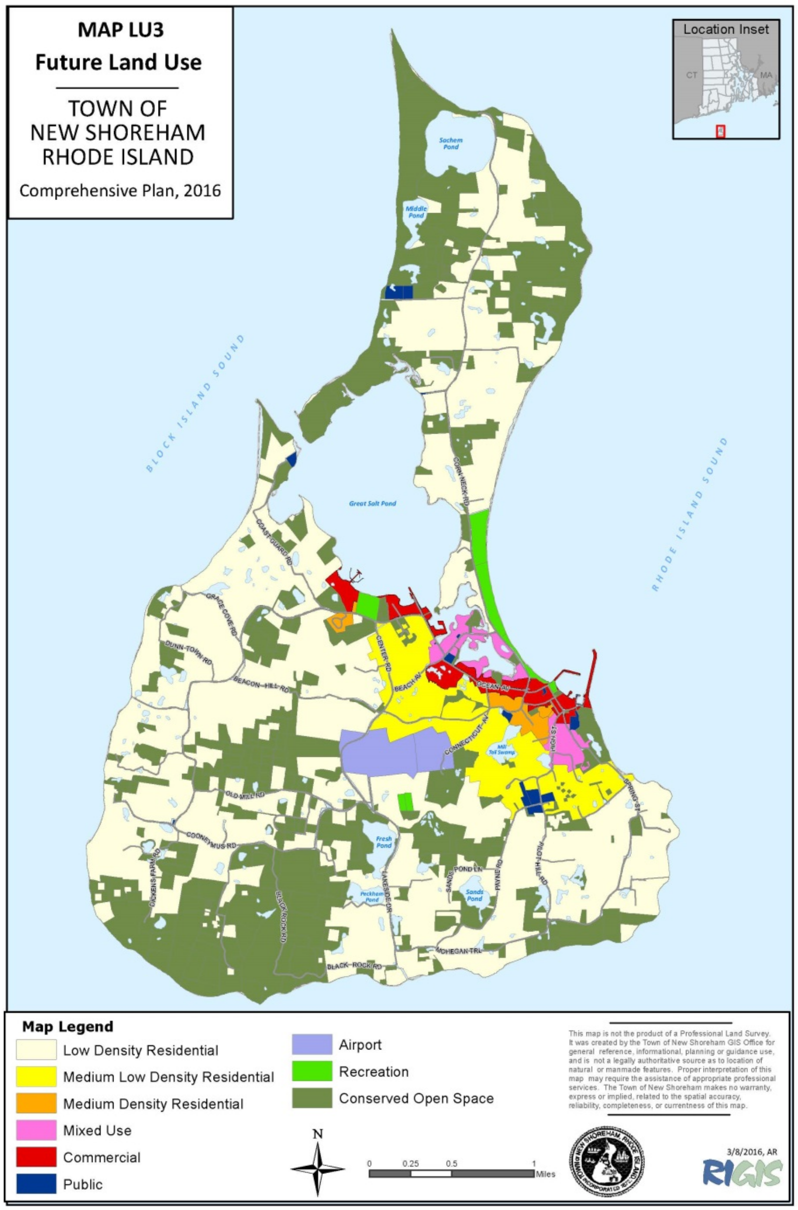


Figure 5-2. Projected future land uses on Block Island (2030).

5.2.2 Urbanization

5.2.2.1 Northern and Southern Analysis Areas

Land use changes will not occur equally across the analysis areas and potential changes are applied according to the best available information and/or according to past or current trends. For example, existing urban areas in all but the New England Analysis Area are assumed to have net expansions by the corresponding percentages for the low (10%) and high (20%) rates based on previous urban growth and an assumption that the most likely areas of future urban expansion and related land use changes are near existing urban areas (Nowak and Walton 2005, p 384-386). Rates of predicted urban growth over 50 years are highly variable within the large analysis areas and range from 0-5% in most areas and up to 20-60 percent in a few large urban areas. The 10% (scenario 1) and 20% (scenario 2) net increases (relative to existing conditions) in urban areas were intended to be conservative estimates for expansion out to 2099. Some urban areas, such as near Tulsa, Oklahoma, are predicted to expand 20-60% (Nowak and Walton 2005, p. 384) and could impact existing ABB habitat, but most urban growth in the analysis areas is predicted to be far less and there are only a few large metropolitan areas in the analysis areas. Most of the Northern and Southern Plains analysis areas are rural with only small urban areas. Some areas are predicted to lose population and are less likely to expand. Population changes do not always represent the area's urban expansion, but can be used to estimate potential future urban growth. Areas with no or low population increases are not expected to have much habitat loss due to urban growth. There are 25 counties in Oklahoma forecasted to experience population decline by 2075 and many of the counties within the ABB range are predicted to have relatively low rates of increase. For example, the Hughes County population is expected to decline and Coal County's population is expected to increase by about 5% by 2075 (Oklahoma Department of Commerce 2012, page 4, 42,76).

5.2.2.2 New England Analysis Area

There are currently about 1,500 houses on Block Island, which is about double the number of houses that were present in 1970. Residential development has been at a pace of about 7-8 houses per year, and the size and massing of houses has increased over the last 30 years (Scott Comings, personal comm. 2016). The most recent Comprehensive Plan, which includes a future land use analysis, conducted by the town of New Shoreham in 2009 predicts a 14% increase in developed land use and about an 18 % increase in protected lands over the next 20 years (from 2010 to 2030)(Figure 5-2). While this analysis of future land use only looks at broad land use classes, it does not appear to predict any major shifts in land use over the next 20 years, with proportional growth predicted for both developed and protected lands. For the New England Analysis Area urban expansion is limited by large areas of protected lands. At some point urban expansion will be reduced due to the relatively high percentage of protected lands (currently 41%

of Block Island and 33% of Nantucket Island). If a 14% increase is predicted for 20 years, we assume a 20% net increase (relative to existing urban areas) in urban growth could be expected out to 2099 if urban expansion continues at a decreasing rate over that time period. We assumed a 20 % net increase for urban growth out to 2099 to represent conditions for scenario 1 and a 30% net increase in urban growth to represent accelerated growth for scenario 2.

5.3 FUTURE LAND USE SCENARIOS

Risks described above, either alone or in combination, could affect the resiliency of ABB populations, further reducing the overall redundancy and representation of the species. With a large range of interconnected populations, the species would have historically been more resilient to stochastic events such as land use changes and climate change. If some populations were extirpated by such events, they could be recolonized or expand into new habitat over time by dispersal from nearby populations. This level of connectivity likely made for a highly resilient species overall. However, under current conditions, restoring that connectivity on a large scale is not feasible due to extirpation of large portions of the historic range and changes in land uses that have created large areas of unfavorable habitat around some existing populations. As a consequence of these current conditions, the viability of the ABB may now depend on maintaining existing known populations and potentially restoring new populations, where feasible. The following scenarios (Table 5-1) evaluate a potential range of future conditions within each of the seven analysis areas and its potential effects to those populations and overall viability of the species. A general discussion of land uses that may affect ABBs is provided in chapters 3 and 4 and additional justification for why these scenarios were chosen is provided in sections 5.2.1 and 5.2.2.

Table 5-1. Scenarios used for future condition analysis.

	Land use Change	Protection/Management
Scenario 1	Land use change is assumed to continue at current rates	Management of existing lands continues, with additional lands established
Scenario 2	Land use changes are accelerated	No intentional management for ABB

5.3.1 Scenario 1 – Continued Current Rate of Land Change and High Protection/Management

Under this scenario, land use change is assumed to continue at approximately current rates and management of most private lands is assumed to be maintained at the status quo. Management of all existing protected lands is assumed to be continuing.

All urban areas in the Northern and Southern Plains analysis areas were assumed to have a 10% net increase (relative to existing urban areas) for predicting land use changes by 2099, as described above. This is an assumed net increase for total acres of urban habitat, although we know there are likely to be reductions in some areas and increases in others. Urban areas in the New England Analysis Area were assumed to increase by a net of 20% by 2099 (see discussion in section 5.2.1.2). For all three analysis areas in the Northern Plains we assumed a 5% net increase in acres of agricultural row crop by 2099, as described above. This is an assumed net increase in row crop acres relative to existing conditions, although we know there are likely to be reductions in some areas and increases in others. For Southern Plains analysis areas we assumed a net 2% increase in acres of permanent habitat loss (relative to current conditions) due to agricultural land use changes. To assess temporary impacts of agricultural impacts we assumed 30% of conditional lands could be affected by high grazing or hay production pressure, as described above. After assessing land use change, when then incorporated climate change projections at time intervals of years 2039, 2069, and 2099. Uncertainties are addressed in each appropriate section, but a summary of uncertainties for Scenario 1 include:

- The land use changes are variable between and within the analysis areas, but rates of changes were estimated using the best available information and assumed to represent the entire Northern and Southern Plains areas.
- Land use changes are variable over time and can fluctuate due to market and economy conditions. The rates used for this scenario are based on current and previous rates of change and assumed to continue at a similar rate.
- The percent of conditional lands that are suitable habitat can change due to land use practices, intensity of the uses, and weather conditions during the growing season.
- Population abundance and distribution assessments are based on ABB survey results and survey effort is limited in portions of the range.

5.3.1.1 Resiliency

Southern Plains Analysis Areas

Red River Analysis Area

Habitat- The 3,251,894 total acres and 2,678,406 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4.1) is large enough to maintain ABB populations, but relatively small compared to other analysis areas. Of the total analysis area, favorable habitat comprises 39%, conditional habitat 37%, and marginal habitat 6%, while the remaining 18% is considered unsuitable. Urban expansion is expected to impact 9,900 acres (0.4%) of suitable habitat and long-term agricultural changes are expected to impact 3007 acres (0.1% of suitable habitat) under this scenario by 2099. Assuming 30% of the conditional lands could be affected by high grazing pressure, 362,082 acres (13.5% of suitable habitat) of conditional lands would be at least temporarily changed to unfavorable lands. This would not change the condition for available habitat (considered Good, Table 5-2) in this analysis area, because the combined losses of urban expansion, long-term agricultural changes, and conditional habitat impacted during droughts (374,959 acres) are only 14% of the suitable acres and do not reduce suitable habitat acres to less than 2,000,000. Not all of the land use changes are likely to occur in suitable habitat so the actual impacts are likely to be less than the percentages described above.

Protected Areas- This analysis area has 123,779 acres of managed and 23,997 acres of multi-purpose protected lands. Protected areas include U.S. Forest Service, Department of Defense, USFWS National Wildlife Refuge, and ODWC wildlife management area lands. Some areas formally supported ABBs, but positive surveys have documented presence on only one of these lands since 2008 (see Table 4-2 Protected Lands). Protected areas are not likely to be affected by the land use changes assumed under scenario 1, therefore will remain in fair condition.

Relative Abundance - This analysis area has a low ratio of positive to negative surveys with no significant concentrations (relative to other Analysis Areas) in the last 10 years (See Table 4-3 and Figure 4-13 for a comparison of survey trends over the last 15 year time frames). The Red River Analysis Area formerly supported areas with good ABB catch rates in the southeastern portion, but positive/negative ratios and catch rates have declined since the early 2000s. No positive surveys have been documented in the Arkansas or Texas portions within the last 7 years and only a few positive surveys are known in Oklahoma since 2006. The relatively recent decline in relative abundance cannot all be attributed to land use changes. Other factors such as the invasion of fire ants may contribute to the ABB decline, but fire ants had become established in this area more than 10 years prior to the decline (see section 4.4.2). Survey effort has been relatively low in recent years, but ratios of positive to negative surveys are far below all other analysis areas and rated as poor with or without any future land use changes. ABBs also disappeared from protected areas like Camp Maxey, TX, with no significant land use changes. Land use changes in the few portions of this analysis area that still support ABBs could possibly reduce the remaining abundance. The current rating is considered poor and under Scenario 1, the future abundance would be expected to remain poor.

Population Distribution - Distribution is currently poor with only a few positive surveys in the central and western portion of the analysis area in the last 7 years. The relatively recent decline in distribution cannot all be attributed to land use changes and ABBs also disappeared from protected areas with no land use changes. Land use changes in the few portions of this analysis area that still support ABBs could possibly reduce the remaining distribution, but the current distribution was considered poor and under Scenario 1, distribution would likely continue to be poor in the future.

Summary of Land Use Effects on the Red River Analysis Area – There are no changes, relative to the existing conditions (Table 5-2) anticipated in condition categories for future habitat or population factors, thus resiliency under scenario 1 for land use changes alone is not expected to change. There are no major urban areas in this analysis area and any changes in rural land uses are expected to be relatively minor.

Table 5-2. Future resiliency of Red River Analysis Area based on projected habitat and population factors under scenario 1 out to 2099.

Red River Analysis Area					
SCENARIO 1 - Continued Rates of Land Change and High Protection/Management					
	Future Habitat Factors		Future Population Factors		
CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
LOW	Good	Fair	Poor	Poor	LOW
See Chapter 4 for narrative	Still large enough to maintain ABB population, but relatively small compared to other AAs.	Presence documented on only one existing protected property since 2008. 3rd lowest total acres compare to other AAs	Significant decline of ABB captures in the last 10 years, which is expected to continue but only partially due to future land use changes.	Population distribution currently poor and some future land use changes could reduce distributions further.	Future land use is not expected to change the resiliency of ABBs within this analysis area.

Arkansas River Analysis Area

Habitat – The Arkansas River Analysis Area is the largest of the seven analysis areas. This analysis area contains 17,753,431 total acres and 14,470,603 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1). Of the total analysis area, favorable habitat comprises 46%, conditional habitat 33%, marginal habitat 3% and unsuitable habitat is 18.2%. Urban expansion is expected to impact 1,447,060 acres and long-term agricultural changes are expected to impact 8,450.54 acres under this scenario by 2099. Effects to habitat associated with extended droughts would tend to increase grazing pressure on pasture lands and reduce the ABB habitat conditions on a large, but unknown, percentage of the conditional land covers. As an example, assuming up to 30% of the conditional lands could be affected by high grazing pressure, 1,740,052; acres of conditional lands would be at least temporarily changed to unfavorable habitat. However, the resiliency for this analysis area is not as sensitive to conversions from conditional to unfavorable lands because of its large amount of favorable habitat (8,134,009 acres). Land use changes under this scenario would not change the resiliency condition (good) for available habitat in this analysis area, because the combined losses of urban expansion, long-term agricultural changes, and conditional habitat impacted during droughts (3,195,563 acres) are only 22.1% of the suitable acres and do not reduce suitable habitat acres to less than 2,000,000. Not all of the land use changes are likely to occur in suitable habitat so the actual impacts are likely to be less than the percentages described above.

Protected Areas - The Arkansas River Analysis Area includes 1,486,002 acres of managed and 933,608 acres of multi-purpose protected lands. Protected areas include multiple federal, state and private areas and many are known to support ABBs, (see Table 4-2 Protected Lands). Several large DOD lands support large populations of ABBs and these areas are likely to remain protected into the future. Protected areas could expand with additional mitigation and expansions of conservation banks. ABB habitat on these lands would be managed and conditions would be maintained or enhanced under this scenario.

Relative Abundance - This analysis area has a fair ratio of positive to negative surveys (26%) with several areas of concentrated positive surveys in the last 15 years (Figure 4-12, year timeframe Table 4-3 for positive to negative ratios.). Trends have demonstrated strong fluctuations, with good recovery following periodic declines over the last 15 years. Land use changes in scenario 1 are not expected to change relative abundance much in areas of concentrations and several large DOD and other protected areas have relatively high positive to negative ratios in most years. The highest known concentrations of ABBs (within the Southern Plains) are in this analysis area. The current ratio is near the bottom of the fair category and the ratio depends strongly on what portion of the surveys are conducted in areas of concentrations verses areas with lower densities. Most of the annual surveys are conducted for proposed projects and are highly variable in location. Due to the factors above, positive to negative ratios could fluctuate but future relative abundance is expected to remain fair under scenario 1.

Population Distribution - The distribution is currently good with some positive surveys in all portions of the analysis area and scattered concentrations of positive surveys in all but the northeastern portion. The areas of concentrated positive surveys are not contiguous and may illustrate areas of habitat fragmentation, but most of the concentrated areas are not widely separated (Figure 4-12). Land use changes in scenario 1 are not likely to significantly affect the overall distribution or change the rating of good because areas of concentrations are not near urban areas or are protected lands. Land uses are likely to change much in the rural areas and are distributed to represent the east, south and western portions of the analysis area. However, continued fragmentation near Tulsa, OK, could potentially create an area of unsuitable habitat that would isolate the ABBs in the Flint Hills Analysis Area from the Arkansas River Analysis Area.

Summary of Land Use Effects on the Arkansas River Analysis Area – There are no changes, relative to the existing conditions (Table 5-3), anticipated in condition categories for future habitat or population factors or resiliency under scenario 1 for land use changes alone. There are urban areas in this analysis area, but they are not near areas of ABB concentrations or those concentrations are on protected lands, so urban expansion would have limited effects. Most of this analysis area is rural and any changes in rural land uses are expected to be minor.

Table 5-3. Future resiliency of Arkansas River Analysis Area based on projected habitat and population factors under scenario 1 out to 2099.

Arkansas River Analysis Area					
SCENARIO 1 - Continued Rates of Land Change and High Protection/Management					
	Future Habitat Factors		Future Population Factors		
CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
HIGH	Good	Good	Fair	Good	HIGH
See Chapter 4 for narrative	Largest amount of suitable habitat of the seven analysis areas. Even with projected land use change, amount favorable habitat will remain high.	Over 2 million acres of protected lands, including conservation banks for the ABB	Highest known concentration of ABB within Southern Plains AAs is in this area. Periodic annual decline show strong rebounds.	ABB distributions spread out throughout most of this, relatively large area, with some fragmentation	Future land use is not expected to change the resiliency of ABBs within this analysis area.

Flint Hills Analysis Area

Habitat - There are 3,706,908 total acres and 2,846,079 suitable acres (combined favorable, conditional and marginal land cover types (Table 4-1), making this a small-medium sized area relative to other analysis areas. Of the total analysis area, favorable habitat comprises 18%, conditional habitat 58%, marginal habitat 0.1% and unsuitable is 23.2%. Conditional habitat is a large percentage of the total area making it relatively vulnerable to changes in land uses. A large percentage of this analysis area is affected by frequent large-scale prescribed burns that can occur on nearly an annual basis. Burning is good for ABB habitat if the frequency is reduced to every 3-5 years to allow recovery of habitat for potential carrion species like cotton rats, but annual burning of large areas can reduce habitat suitability for these species. Burning of pastures to improve grazing conditions is likely to continue in the future, but annual burning may be reduced or more restricted relative to existing conditions, due to concerns for air quality, human health, liability, property and safety. Urban expansion is expected to impact 13,470 acres and long-term agricultural changes are expected to impact 5,583 acres under this scenario by 2099. Effects to habitat associated with droughts, would tend to increase grazing pressure on pasture lands and reduce the ABB habitat conditions on a large percentage of the conditional land covers. Assuming 30% of the conditional lands could be affected by high grazing pressure/mowing for hay, 645,938 acres of conditional lands would be at least temporarily changed to unfavorable lands. Land use changes under this scenario would not change the resiliency condition of good for available habitat in this analysis area, because the combined losses of urban expansion, long-term agricultural changes, and conditional habitat in an unfavorable condition (664,991 acres) are only 23% of the suitable acres and do not reduce suitable habitat acres to less than 2,000,000. Not all of the land use changes are likely to occur in suitable habitat so the actual impacts are likely to be less than the percentages described above.

Protected Areas- There are 133,196 acres of managed, 52,114 acres of multi-purpose and about 43,000 acres of tribal protected lands. Protected areas include federal, state, tribal and private areas and many are known to support ABBs, (see Table 4-2 Protected Lands). The ABB is known to occur at several wildlife management areas, and a large TNC prairie preserve. Protection for these areas is likely to continue through 2099 and beyond. ABB habitat on these lands would be managed and conditions would be maintained or enhanced in the future under this scenario. There is some potential for protected lands to increase through mitigation actions, including conservation banks. Future protected areas are expected to remain in the good condition under scenario 1.

Relative Abundance - This analysis area has a relatively low ratio of positive to negative surveys with relatively large fluctuations between years. Preliminary reports for 2016 indicate more positive surveys and a higher ratio of positives. See Figure 4-12 for an overview of the last 15 years, and Table 4-3 for survey results. Trends have demonstrated strong fluctuations, but with good recoveries over the last 10 years and future land use changes are not expected to change the survey ratios or relative abundance. Future relative abundance is expected to remain in the poor condition under scenario 1.

Population Distribution - The Distribution is currently fair with some recent positive surveys in the southern 2/3 of the analysis area and one concentration of positive surveys. The survey effort in portions of this analysis area is limited (see Figure 4-12). Future distribution would be expected to be similar to existing distributions but could improve with more surveys.

Summary of Land Use Effects on the Flint Hills Analysis Area - There are no changes, relative to the existing conditions (5-4), anticipated in condition categories for future habitat or population factors or resiliency under scenario 1 for land use changes alone. There are no large urban areas in this analysis area and any changes in rural land uses are expected to be minor.

Table 5-4. Future resiliency of Flint Hills Analysis Area based on projected habitat and population factors under scenario 1 out to 2099.

Flint Hills Analysis Area					
SCENARIO 1 - Continued Rates of Land Change and High Protection/Management					
	Future Habitat Factors		Future Population Factors		
CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
MODERATE	Good	Good	Poor	Fair	MODERATE
See Chapter 4 for narrative	Although much of the ABB habitat is conditional and vulnerable to land use change, suitable habitat after projected changes remains high	Over 200,000 acres of protected lands, most with documented ABB presence.	This area has a low relative abundance and is expected to remain in this condition	No significant changes to population distrubutions anticipated in this area.	Future land use is not expected to change the resiliency of ABBs within this analysis area.

Northern Plains Analysis Areas

Loess Canyons Analysis Areas

Habitat- There are 2,759,065 total acres and 1,678,054 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1), which is a small area relative to other analysis areas. Of the total analysis area, favorable habitat comprises 29.7%, conditional habitat 30.8%, marginal habitat 0.3% and unsuitable is 38.8%. Conditional habitat is 30.8% of the total area, but conditional habitats in northern analysis areas are less affected by grazing. Grazing is the primary land use on most of the existing suitable ABB habitat and grazing does not appear to negatively affect habitat suitability in northern analysis areas like it does in southern areas (see section 3.2). Conversion of grasslands to cropland is a future threat to suitable habitat. Based on the rates of conversion in past years, we expect a 5% percent net increase in cropland (41,153 acres) by 2099. Urban expansion is expected to impact 6,769 acres. Land use changes under this scenario would not change the resiliency condition of fair for available habitat in this analysis area, because the combined losses of urban expansion, and long-term agricultural changes (47,922 acres) are only 2.9% of the suitable acres and do not reduce suitable habitat acres to less than 1,000,000. However, eastern red cedar has been expanding rapidly in this analysis area due to a lack of fire or other control and land that is dominated by dense stands of cedar are not suitable habitat. This scenario assumes high protection and management and would include management of cedar, but without control of the invasive plant, the available habitat condition would drop from fair to poor. Not all of the land use changes are likely to occur in suitable habitat so the actual impacts are likely to be less than the percentages described above. This would represent a continuation of the status quo level of habitat effects related to changes in land use and the results are presented in Table 5-2.

Protected Areas – There are 15,342 acres of managed and 3,843 acres of multi-purpose protected lands. Most protected areas are known to support ABBs, (see Table 4-2 Protected Lands). ABB habitat on these lands would be managed and conditions would be maintained or enhanced under this scenario. The percentage and total area of protected lands in this analysis area is very low, but there may be some potential to expand protected areas in northern analysis areas.

Relative Abundance - This analysis area has a fair ratio of positive to negative surveys (See Figure 4-12 for the last 15 year time frame, and Table 4-3 for survey results). Trends in survey ratios have demonstrated fluctuations with declines during droughts, but with good recoveries over the last 10 years in normal to wet years. Future land use changes are not expected to change the survey ratios or relative abundance under scenario 1. Land management is assumed to control risks related to expansion of redcedar.

Population Distribution - The distribution is currently fair with one relatively large contiguous concentration of positive surveys in the center of the analysis area (see Figure 4-12). The future distribution would be expected to become more fragmented due to conversions of grassland to croplands and expansion of redcedar in some locations, but remain fair by 2099.

Summary of Land Use Effects on the Loess Canyons Analysis Area - The current resiliency of the analysis area is considered moderate due to the fair habitat availability and area of native habitat, fair distribution, and fair ratios of positive to negative surveys (compared to other analysis areas, see Table 4-3). There are no changes, relative to the existing conditions (Table 5-5), anticipated in condition categories for future habitat or population factors or resiliency under scenario 1 for land use changes alone. There are no large urban areas in this analysis area and any changes in rural land uses are expected to be minor (only 2.9% of the suitable acres).

Table 5-5. Future resiliency of Loess Canyons Analysis Area based on projected habitat and population factors under scenario 1out to 2099.

Loess Canyons Analysis Area					
SCENARIO 1 - Continued Rates of Land Change and High Protection/Management					
	Future Habitat Factors		Future Population Factors		
CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
MODERATE	Fair	Poor	Fair	Fair	MODERATE
See Chapter 4 for narrative	Although much of the ABB habitat is conditional and vulnerable to land use change, remaining suitable habitat after projected changes remains fair	Less than 20,000 acres of protected lands; future protection and management is considered poor relative to other areas.	Fair ratio of positive to negative surveys and past trends show good recovery after declines. No anticipated change.	One relatively large concentration which is not anticipated to change due to future land use.	Future land use is not expected to change the resiliency of ABBs within this analysis area.

<u>*Sandhills Analysis Area*</u>

<u>Habitat -</u> There are 10,819,170 total acres and 8,633,685 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1). Of the total analysis area, favorable habitat comprises 9.9%, conditional habitat 69.7%, marginal habitat 0.2% and unsuitable is 20.2%. This analysis area has the second largest area of suitable habitat of the seven analysis areas. Conditional habitat is nearly 70% of the total area, but conditional habitat in northern analysis areas are less affected by grazing or mowing. Grazing is the primary land use on most of the existing suitable ABB habitat and grazing does not appear to negatively affect habitat suitability in northern analysis areas like it does in southern areas (see section 3.2). Conversion of grasslands to cropland is a future threat to suitable habitat. Based on the rates of conversion in past years, we expect a 5% percent net increase in cropland (71,709 acres) by 2099. Urban expansion (10% net increase) is expected to impact 12,425 acres by 2099. This would not change the resiliency condition (good) for available habitat in this analysis area, because the combined losses of urban expansion and long-term agricultural changes (84,134 acres) are only 1% of the suitable acres and do not reduce suitable habitat acres to less than 2,000,000. Not all of the land use changes are likely to occur in suitable habitat so the actual impacts are likely to be less than the percentages described above. This would represent a continuation of the status quo level of habitat effects related to changes in land use and the results are presented in Table 5-2.

<u>Protected Areas –</u> There are 393,983 acres of managed and 24,633 acres of multi-purpose protected lands in this analysis area. Protected areas are known to support ABBs, (see Table 4-2 Protected Lands). ABB habitat on these lands would be managed and conditions would be

maintained or enhanced under this scenario. There may be some potential to expand protected areas in northern analysis areas.

Relative Abundance - This analysis area has the highest ratio of positive to negative surveys. See Figure 4-12 for the last 15 year time frame, and Table 4-3. Trends have demonstrated fluctuations, but with good recoveries over the last 10 years. Future land use changes under scenario 1 could have local effects, but are not expected to change the relative abundance for the analysis area.

Population Distribution - The distribution is currently good with some positive surveys in all portions of the analysis area and one large contiguous concentration of positive surveys (see Figure 4-12). The future distribution would be expected to become more fragmented due to conversions of grassland to croplands in some locations, but the overall distribution in the Sandhills Analysis Area would not be affected by future land use changes and should remain good by 2099.

Summary of Land Use Effects on the Sandhills Analysis Area - The Sandhills Analysis Area includes 10,819,170 total acres in northcentral portions of Nebraska. The current resiliency of the analysis area is considered high due to the large area of native habitat, good distribution, and high ratios of positive to negative surveys (compared to other analysis areas, see Table 4-3). The land use changes in scenario 1 may have some local impacts, but are relatively minor in this large analysis area (only 1% of the suitable acres) and are not expected to change the resiliency of the Sandhills Analysis Area (Table 5-6).

Table 5-6. Future resiliency of Sandhills Analysis Area based on projected habitat and population factors under scenario 1out to 2099.

Sand Hills Analysis Area					
SCENARIO 1 - Continued Rates of Land Change and High Protection/Management					
	Future Habitat Factors		Future Population Factors		
CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
HIGH	Good	Good	Good	Good	HIGH
See Chapter 4 for narrative	2nd largest analysis area; although much of the ABB habitat is conditional and vulnerable to land use change, remaining suitable habitat after projected changes remains good.	Over 400,000 acres of protected areas which are not expected to decline as a result of projected land use change.	Highest abundance of all analysis areas, which is not expected to change significanly as a result of land use change.	Positive surveys spread throughout the analysis area with no fragmentation, which is not expected to be significantly affecte by future land use.	Future land use is not expected to change the resiliency of ABBs within this analysis area.

Niobrara River Analysis Area

Habitat - There are 4,108,903 total acres and 2,961,469 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1). This is a medium sized area relative to other analysis areas. Of the total analysis area, favorable habitat comprises 6.4%, conditional habitat 65.3%, marginal habitat 0.4% and unsuitable is 27.9%. Grazing is the primary land use on most of the existing suitable ABB habitat and grazing does not appear to negatively affect habitat suitability in northern analysis areas like it does in southern areas (see section 3.2). Conversion of grasslands to cropland is a future threat to suitable habitat. Based on the rates of conversion in past years, we expect a 5% percent net increase in cropland (27,206 acres) by 2099. Urban expansion (10% net increase) is expected to impact 6,670 acres by 2099. This would not change the resiliency condition of good for available habitat in this analysis area, because the combined losses of urban expansion and long-term agricultural changes (33,876 acres) are only 1.1% of the suitable acres and do not reduce suitable habitat acres to less than 2,000,000. Not all of the land use changes are likely to occur in suitable habitat so the actual impacts are likely to be less than the percentages described above. This would represent a continuation of the status quo level of habitat effects related to changes in land use and the results are presented in Table 5-7.

Protected Areas – This analysis area includes 58,918 acres of managed, 33,582 acres of multi-purpose protected lands and a large area of tribal land. (see Table 4-2 Protected Lands). ABB habitat on these lands would be managed and conditions would be maintained or enhanced under this scenario. There may be some potential to expand protected areas in northern analysis areas.

Relative Abundance - This analysis area has a fair ratio of positive to negative surveys (Figure 4-12 and Table 4-3). Trends have demonstrated fluctuations, but with good recoveries over the last 10 years. Future land use changes under scenario 1 could have local effects, but are not expected to change the relative abundance for the analysis area.

Population Distribution – The distribution is currently fair with some positive surveys in all portions of the analysis area and one contiguous concentration of positive surveys (Figure 4-12). The future distribution would be expected to become more fragmented due to conversions of grassland to croplands in some locations, but the overall distribution in the Niobrara River Analysis Area would not be affected by future land use changes in scenario 1and should remain fair by 2099.

Summary of Land Use Effects on the Niobrara River Analysis Area - The Niobrara River Analysis Area includes 4,108,903 total acres in northcentral portions of Nebraska and southcentral portions of South Dakota. The current resiliency of the analysis area is considered moderate due to the moderate area of native habitat, relatively good distribution, and moderate ratios of positive to negative surveys (compared to other analysis areas, Table 4-3). The future land use changes in scenario 1 may have some local impacts, but are relatively minor (only 1.1% of the suitable acres would be affected) and are not expected to change the resiliency of the Niobrara River Analysis Area (Table 5-7).

Table 5-7. Future resiliency of Niobrara River Analysis Area based on projected habitat and population factors under scenario 1out to 2099.

Niobrara River Analysis Area					
SCENARIO 1 - Continued Rates of Land Change and High Protection/Management					
	Future Habitat Factors		Future Population Factors		
CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
MODERATE	Good	Poor	Fair	Fair	MODERATE
See Chapter 4 for narrative	Although much of the ABB habitat is conditional and vulnerable to land use change, remaining suitable habitat after projected changes remains good.	Over 90,000 acres of protected lands, but no lands being managed specifically for ABBs. This condition is not expected to change under future land use.	Abundace is not expected to change significanltly as a result of future land use changes.	Future conditions may become more fragmented due to land conversions, but should remain in fair condition.	Future land is not expected to change the resiliency of ABBs within this analysis area.

New England Analysis Area

The New England Analysis Area consists of two islands where ABBs are known to occur: Block Island, RI and Nantucket, MA. The total combined acres of suitable habitat for both islands are 25,865 and there are 13,939 acres of protected lands. The current resiliency of the analysis area is considered moderate due to the limited area of potential habitat (considered poor condition), relatively good distribution, and moderate ratios of positive to negative surveys (compared to other analysis areas, see Table 4-3).

Block Island is considered to have moderate resiliency with active management. Nantucket is a reintroduced population with lower resiliency with lower ratios of positive to negative surveys. Land use changes and effects to ABBs are predicted to be relatively minor through 2099 because over 41% of Block Island and 33% of Nantucket Island habitat is protected. No conversion to cropland is expected in this analysis area and the only anticipated habitat impacts due to land uses is a 20% net increase in urban acres (see discussion in section 5.2.1.2). Urban expansion is expected to impact about 326 additional acres on Block Island and 438 additional acres on Nantucket Island by 2099 under scenario 1. The impacts due to urban expansion are anticipated to be partially offset by increases in protected lands. The current resiliency (moderate) would be maintained under scenario 1 (Table 5-8).

Table 5-8. Future resiliency of the New England Analysis Area based on projected habitat and population factors under scenario 1out to 2099.

New England Analysis Area					
SCENARIO 1 - Continued Rates of Land Change and High Protection/Management					
	Future Habitat Factors		Future Population Factors		
CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
MODERATE	Poor	Poor	Fair	Fair	MODERATE
See Chapter 4 for narrative	Both islands have less than 30,000 acres of suitable habitat, and impacts from future land use change is expected to be minor	Nearly 14,000 acres of protected lands between both islands with effective species management. Not expected to change.	Relative abundance remains fair with only minor effects from future land use change.	Population distribution remains fair with only minor effects from future land use change.	Future land use is not expected to change the resiliency of ABBs within this analysis area.

Summary of Land Use Change Effects on Resiliency for Scenario 1

Southern Plains Analysis Areas - Some types of land use changes are relatively common in portions of the southern analysis areas, but rare in the remainder of the existing ABB range. For example, oil and gas development can have locally significant impacts to habitat in portions of the southern analysis areas; however, overall permanent impacts to ABB habitat are less than 1% of available habitat in the southern analysis areas and relatively minor compared to agriculture or urban expansion (see section 3.2 for addition discussion on oil and gas). Under scenario 1, the Industry Conservation Plan would continue to provide off-setting mitigation for oil and gas impacts that would provide large blocks of managed habitat with long-term protection.

For all three southern analysis areas, the primary land uses are related to agriculture. Agricultural land uses and urban expansion are predicted to have some impacts to ABB habitat over time, but the impacts affect a relatively small percentage of the analysis areas. There are no changes anticipated in condition categories for future habitat, population factors or resiliency under scenario 1 for land use changes alone (Table 5-9). There are some urban areas in the Southern Plains analysis areas, but they are not near any areas of ABB concentrations or the concentrations near urban areas are on protected lands that would not be affected by urban expansion. Most of these analysis areas are rural and any changes in rural land uses are expected to be minor under scenario 1.

Table 5-9. Current and Future resiliency of American burying beetle analysis areas based on future habitat and population factors under Scenario 1.

Scenario 1 - Continued Rates of Land Change and High Protection/Management						
		Future Habitat Factors		Future Population Factors		
Analysis Area	CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
Niobrara River	**Moderate**	Good	Poor	Fair	Fair	**Moderate**
Sand Hills	**High**	Good	Good	Good	Good	**High**
Loess Canyons	**Moderate**	Fair	Poor	Fair	Fair	**Moderate**
Flint Hills	**Moderate**	Good	Good	Poor	Fair	**Moderate**
Arkansas River	**High**	Good	Good	Fair	Good	**High**
Red River	**Low**	Good	Poor	Poor	Poor	**Low**
New England	**Moderate**	Poor	Poor	Fair	Fair	**Moderate**

Northern Plains Analysis Areas

For all three Northern Plains analysis areas, there are no changes anticipated in condition categories for future habitat, population factors or resiliency under scenario 1 for land use changes alone (Table 5-9). There are few urban areas in the Northern Plains analysis area. Most of these analysis areas are rural and any changes in rural land uses are expected to be minor under scenario 1. The combined impacts of urban expansion and conversion to cropland are expected to affect only about 1-3 % of the suitable habitat in each analysis area. Not all of the land use changes are likely to occur in suitable habitat so the actual impacts are likely to be less than the percentages described above.

This assessment of land use effects includes cautions due to our limited ability to quantify some potential future effects. For example, uncommon increases in crop prices could increase incentives for conversion of grassland to row crops to levels beyond the assumptions used in this scenario. Also, recent development and potential expansion of wind energy projects could add to impacts from other land use changes. The construction of wind turbines, roads, and powerlines has direct permanent habitat impacts and fragments the remaining habitat. The operation of wind turbines also has potential for direct take through ABB collisions with the blades. The collisions of blades with birds and bats could increase the abundance of carcasses and attract ABBs to the area. Indirect effects include changes to potential carrion populations, carrion availability, and abundance of potential competing scavengers such as skunks, raccoons, opossums, coyotes, and crows. The combination of fragmented habitat and collision-related carcasses could attract more scavengers and increase competition with ABBs for carcasses. Another potential indirect effect is the increased potential for conversion of grassland to row crops due to improved road access and available electrical power lines for running electric pumps for irrigation.

Future land use effects related to wind power were not factored into scenario 1 because we did not have estimates of future development or total areas that may be affected by wind projects and there are no studies available to evaluate the actual effects of wind projects on ABBs. The current area of wind projects is relatively small and there are 6,471 wind turbines registered in the Northern Plains Analysis Areas, but we do not know what areas, or what percentage of the suitable habitat in Northern Plains analysis areas may be affected by wind projects in future years.

New England Analysis Area

The current resiliency of the analysis area is considered moderate due to the limited area of potential habitat (considered poor condition), relatively good distribution, and moderate ratios of positive to negative surveys (compared to other analysis areas, see Table 4-3).

Block Island is considered to have moderate resiliency with active management. Nantucket is a reintroduced population with lower resiliency with lower ratios of positive to negative surveys, but relative abundance and resiliency can be maintained with continued provisioning and active management. Land use changes and effects to ABBs are predicted to be relatively minor through 2099 because over 41% of Block Island and 33% of Nantucket Island habitat is protected. No conversion to cropland is expected in this analysis area and the only anticipated habitat impacts due to land uses is a 20% net increase in urban acres relative to existing conditions (see discussion in section 5.2.1.2). Urban expansion is expected to impact about 326 additional acres on Block Island and 438 additional acres on Nantucket Island by 2099 under scenario 1. The impacts due to urban expansion are anticipated to be partially offset by increases in protected lands. The current resiliency (moderate) would be maintained under scenario 1, largely due to active management.

5.3.1.2 Representation

Geographic distribution of occupied and potentially suitable habitat and genetic information is being used to describe representation for the ABB. Under Scenario 1, with all analysis areas maintaining their existing resiliency, the breadth of genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the species' range are not likely to be reduced (relative to current conditions).

5.3.1.3 Redundancy

For the ABB, we are using the number and geographic distribution of populations (measured through survey data) and of occupied and potentially suitable habitat, as described by survey data and geospatial analyses, to measure redundancy. Current redundancy is 8-9 'populations', three in the Southern Plains (Arkansas River, Red River, and Flint Hills), three in the Northern Plains (Niobrara, Sandhills, and Loess Canyons), two within the New England Analysis Area (Block Island and Nantucket) and one in Missouri. Introduced populations in Missouri and Ohio could increase the redundancy if they are successful. The Missouri reintroduction is relatively new, but appears to be successful and could be considered another population under scenario 1 with continued management. Scenario 1 could have minor effects to the distribution of populations, but the changes in land uses should not extirpate any populations and future redundancy would be maintained with existing number of populations. The future redundancy could be reduced if the Red River population continues to decline and does not recover, but the relatively recent decline cannot all be attributed to land use changes.

5.3.1.4 Summary of Viability for Scenario 1

For all analysis areas, there are no changes anticipated in condition categories for future habitat, population factors or resiliency under scenario 1 for land use changes alone (Table 5-9). Agricultural land uses and urban expansion are predicted to have some impacts to ABB habitat over time, but the impacts affect a relatively small percentage of the analysis areas. There are some urban areas in the Southern Plains analysis areas, but they are not near any areas of ABB concentrations or the concentrations near urban areas are on protected lands that would not be affected by urban expansion. Most of these analysis areas are rural and any changes in rural land uses are expected to be minor under scenario 1. Not all of the land use changes are likely to occur in suitable habitat so the actual impacts are likely to be less than the percentages described for each analysis area. The land use changes under scenario 1, (with high protection/management or best case) would result in only minor reductions relative to the current viability and population resiliencies. Future ABB representation and redundancy should not be affected by scenario 1 out to 2099.

5.3.2 Scenario 2 – Accelerated Rate of Land Change, Low Management

Under this scenario, land use changes are increased and there is no intentional management for ABBs. Management for ABBs would continue at existing mitigation banks because they are obligated and funded to do that, but there would be no expansion of existing banks and no new banks would be established. Some land management for other species or other purposes may directly or indirectly benefit ABBs, but no specific management for ABBs would be initiated or maintained (except at existing mitigation banks). No new reintroductions would be attempted and management for ABBs would not continue at current reintroduction sites. No monitoring or supplementation of carcasses (such as the current practices in New England) would occur. All urban areas in the Northern and Southern Plains analysis areas are buffered by a 20 % net increase and New England is buffered by 30% net increase in urban acres for predicting land use changes by 2099. All three analysis areas in the Northern Plains assumed a 30% net increase in agricultural conversion to row crop by 2099. Southern analysis areas assumed a net 5% increase in permanent habitat loss due to agricultural land use changes. To assess temporary impacts of agricultural impacts we assumed 60% of the conditional lands in the southern analysis areas could be affected by high grazing pressure during droughts, conditional lands would be at least temporarily changed to unfavorable lands.

Uncertainties are addressed in each appropriate section, but a summary of uncertainties for Scenario 2 include:

- The land use changes are variable between and within the analysis areas, but rates of changes used were estimated using the best available information and assumed to represent the entire Northern and Southern Plains areas.
- Land use changes are variable over time and can fluctuate due to market and economy conditions. The rates used for this scenario are based on current and previous rates of change.
- The percent of conditional lands that are suitable habitat can change due to land use practices, intensity of the uses, and weather conditions during the growing season.
- Population abundance and distribution assessments are based on ABB survey results and survey effort is limited in portions of the range.

5.3.2.1 Resiliency

Southern Plains Analysis Areas

Red River Analysis Area

Habitat- The 3,251,894 total acres and 2,678,406 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4.1) is large enough to maintain ABB populations, but relatively small compared to other analysis areas. Of the total analysis area, favorable habitat comprises 39%, conditional habitat 37%, and marginal habitat 6%, while the remaining 18% is considered unsuitable. Urban expansion is expected to impact 19,799 acres (0.7%) of suitable habitat and long-term agricultural changes are expected to impact 7,517 acres (0.3% of suitable habitat) under this scenario by 2099. Assuming 60% of the conditional lands could be affected by high grazing pressure and hay production during droughts, 724,163 acres (27% of suitable habitat) of conditional lands would be at least temporarily changed to unfavorable lands. This could change the condition for available habitat from the current good condition to fair in some years. The combined losses of urban expansion, and long-term agricultural changes are 27,316 acres and would not change the current condition, but dry conditions, the additional 724,163 acres of temporary impacts to conditional habitat brings the total impacted acres to 751,479 (28% of the suitable acres) and reduces suitable habitat acres to less than 2,000,000. Not all of the land use changes are likely to occur in suitable habitat so the actual impacts are likely to be less than the percentages described above.

Protected Areas- This analysis area has 123,779 acres of managed and 23,997 acres of multi-purpose protected lands. Protected areas include U.S. Forest Service, Department of Defense, USFWS National Wildlife Refuge, ODWC wildlife management area lands. Some areas formally supported ABBs, but positive surveys have documented presence on only one of these lands since 2008 (see Table 4-2 Protected Lands). Some of these areas would be managed for other wildlife in ways that would benefit ABBs, but no management is specifically for ABBs. The habitat factor condition for protected areas is not expected to change under scenario 2 and would remain fair.

Relative Abundance - This analysis area has a low ratio of positive to negative surveys with no concentrations in the last 10 years (See Table 4-3 and Figure 4-13 for a comparison of survey trends over the last 15 year time frames). The Red River Analysis Area formerly supported areas with good ABB catch rates in the southeastern portion, but positive/negative ratios and catch rates have declined since the early 2000s. Camp Maxey in Texas supported good positive/negative ratios in 2005, but those declined through 2008. No positive surveys have been documented in the Arkansas or Texas portions within the last 7 years and only a few positive surveys are known in Oklahoma since 2006. The relatively recent decline in relative abundance cannot all be attributed to land use changes. Survey effort has been relatively low in recent years, but ratios of positive to negative surveys are far below all other analysis areas and rated as poor with or without any future land use changes. ABBs also disappeared from protected areas with no significant land use changes. The declines in relative abundance occurred over a 3-5 year period and it is unlikely that land use changes occurred on a scale that could account for the reduced relative abundance. It is possible that the relative abundance could recover to some degree, but scenario 2 does not propose land management to support a recovery. The scenario 2 level of land use changes in the portions of this analysis area that still support ABBs could possibly reduce the remaining abundance, but the current rating is considered poor and under Scenario 2 land use changes, relative abundance would remain poor (see Table 5-10).

Population Distribution - Distribution is currently poor with only a few positive surveys in the western and central portions of the Red River Analysis Area in the last 7 years. The relatively recent decline in distribution cannot all be attributed to land use changes and ABBs also disappeared from protected areas with no land use changes. Land use changes in the few portions of this analysis area that still support ABBs could possibly reduce the remaining distribution, but the current distribution was considered poor and under Scenario 2 land use changes, distribution would likely continue to be poor in the future.

Summary of Land Use Effects on the Red River Analysis Area – There are minor changes, relative to the existing conditions (see Table 4-5 and 5-11), anticipated in condition categories for future habitat, but other habitat or population factors do not change. Resiliency does not change under scenario 2 for land use changes alone. There are no major urban areas in this analysis area and any changes in rural land uses are expected to be relatively minor. The current resiliency for this analysis area is poor and land use changes may impact some of the remaining ABBs, but the land use changes alone under scenario 2 are not likely to extirpate ABBs from this analysis area. The future resiliency under scenario 2 with land use changes alone would remain low (see Table 5-11).

Table 5-10. Future resiliency of Red River Analysis Area based on projected habitat and population factors under scenario 2 out to 2099.

Red River Analysis Area					
SCENARIO 2 - Increased Rates of Land Change and Low Protection/Management					
	Future Habitat Factors		Future Population Factors		
CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
LOW	Good to Fair	Fair	Poor	Poor	LOW
See Chapter 4 for narrative	Large area, but suitable habitat reduced to less than 2 million acres during drought years.	Presence documented on one existing protected lands since 2008. 3rd lowest total acres compare to other AAs	Significant decline of ABB captures in the last 10 years, decline is expected to continue and not necessarily related to land use changes.	Population distribution currently poor and future land use changes could reduce distributions further.	Higher rates of land use change and low protection and management is not expected to change the resiliency of ABBs within this analysis area.

Arkansas River Analysis Area

Habitat – The Arkansas River Analysis Area is the largest of the seven analysis areas. This analysis area contains 17,753,431 total acres and 14,470,603 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1). Of the total analysis area, favorable habitat comprises 46%, conditional habitat 33%, marginal habitat 3% and unsuitable habitat is 18.2%. Urban expansion (20% net increase) is expected to impact 156,930 acres and long-term agricultural changes (5% net increase) are expected to impact 21,149 acres under this scenario by 2099. Effects to habitat associated with extended droughts, would tend to increase grazing pressure on pasture lands and reduce the ABB habitat conditions on a large, but unknown, percentage of the conditional land covers. As an example, assuming up to 60% of the conditional lands could be affected by high grazing pressure and hay production during droughts, 3,552,553 acres of conditional lands would be at least temporarily changed to unfavorable lands. However, the resiliency for this analysis area is not as sensitive to conversions from conditional to unfavorable lands because it is large and has 8,134,009 acres of favorable habitat. This would not change the resiliency condition of good for available habitat in this analysis area, because the combined losses of urban expansion, long-term agricultural changes, and conditional habitat impacted during droughts (3,730,632 acres or about 26% of the suitable habitat) still leaves about 10,739,971 acres of suitable habitat. Not all of the land use changes are likely to occur in suitable habitat so the actual impacts are likely to be less than the percentages described above.

Protected Areas- The Arkansas River Analysis Area includes1, 486,002 acres of managed and 933,608 acres of multi-purpose protected lands. Protected areas include multiple federal, state and private areas and many are known to support ABBs, (see Table 4-2 Protected Lands). Several large DOD lands support large populations of ABBs and these areas are likely to remain protected into the future. The habitat factor condition for protected areas is not expected to change under scenario 2 land use changes and would remain good.

Relative Abundance - This analysis area has a fair ratio of positive to negative surveys (26%) with several areas of concentrated positive surveys in the last 15 years (Figure 4-12, year timeframe Table 4-3 for positive to negative ratios.). Trends have demonstrated strong fluctuations, with good recovery following periodic depletions over the last 15 years. Land use changes in scenario 2 are not expected to change relative abundance much in areas of concentrations and several large DOD and other protected areas have relatively high positive to negative ratios in most years. The highest known concentrations of ABBs (within the Southern Plains) are in this analysis area. The current ratio is near the bottom of the fair category and land use changes could cause this to fall into the poor category. The ratio depends strongly on what portion of the surveys are conducted in areas of concentrations versus areas with lower densities. Most of the annual surveys are conducted for proposed projects and are highly variable in location.

Population Distribution - The distribution is currently good with some positive surveys in all portions of the analysis area and scattered concentrations of positive surveys in all but the northeastern portion. The areas of concentrated positive surveys are not contiguous and may illustrate areas of habitat fragmentation, but most of the concentrated areas are not widely separated (see Figure 4-12). Land use changes in scenario 2 are not likely to significantly affect the overall distribution or change the rating of good because areas of concentrations are not near urban areas or are protected lands. ABB concentrations are in areas that are not conducive to intensive agricultural use due to topography and soils. ABBs distribution would continue to represent the east, south and western portions of the analysis area. However, some areas of concentration may become more isolated from others. Continued fragmentation near Tulsa, OK, could potentially create an area of unsuitable habitat that would isolate the ABBs in the Flint Hills Analysis Area from the Arkansas River Analysis Area.

Summary of Land Use Effects on the Arkansas River Analysis Area – There could be minor changes for future relative abundance and distribution relative to the existing conditions (see Table 4-5 and 5-11), under scenario 2 land use changes. There are urban areas in this analysis area, but they are not near most areas of ABB concentrations or there are protected lands that would limit urban growth. Most of this analysis area is rural and any changes in rural land uses are expected to be minor in the current areas of ABB concentrations. The combined permanent loss of habitat due to urban and agricultural expansion (178,079 acres) is minor in this large analysis area.

Table 5-11. Future resiliency of Arkansas River Analysis Area based on projected habitat and population factors under scenario 2 out to 2099.

Arkansas River Analysis Area					
SCENARIO 2 - Increased Rates of Land Change and Low Protection/Management					
	Future Habitat Factors		Future Population Factors		
CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
HIGH	Good	Good	Fair	Good	HIGH
See Chapter 4 for narrative	Largest amount of suitable habitat of the seven analysis areas. Even with high rates of land use change, amount favorable habitat will remain high.	Over 2 million acres of protected lands, including conservation banks for the ABB	Highest known concentration of ABB within Southern Plains AAs is in this area. Periodic annual decline show strong rebounds.	ABB distributions spread out throughout most of this, relatively large area, with some fragmentation. Not expected to significantly change.	Higher rates of land use change and low protection and management is not expected to change the resiliency of ABBs within this analysis area.

Flint Hills Analysis Area

Habitat - There are 3,706,908 total acres and 2,846,079 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1), making this a small-medium sized area relative to other analysis areas. Of the total analysis area, favorable habitat comprises 18%, conditional habitat 58%, marginal habitat 0.1% and unsuitable is 23.2%. Conditional habitat is a large percentage of the total area and makes it relatively sensitive to changes in land uses. Urban expansion (20% net increase) is expected to impact 26,940 acres and long-term agricultural changes (5% net increase) are expected to impact 13,958 acres under this scenario by 2099. A large percentage of this analysis area is affected by frequent large-scale prescribed burns that can occur on nearly an annual basis. Burning is beneficial to ABB habitat if the frequency is reduced to every 3-5 years to allow recovery of habitat for potential carrion species like cotton rats, but annual burning of large areas can reduce habitat suitability for these species. Burning of pastures to improve grazing conditions is likely to continue in the future, but annual burning may be reduced or more restricted relative to existing conditions, due to concerns for air quality, human health, liability, property and safety. Effects to habitat associated with droughts (see section 3.2 and 3.8), would tend to increase grazing pressure on pasture lands and reduce the ABB habitat conditions on a large percentage of the conditional land covers. Assuming 60% of the conditional lands could be affected by high grazing pressure/mowing for hay, 1,291,876 acres of conditional lands would be at least temporarily changed to unfavorable lands. This could change the condition for available habitat from the current good condition to fair (Table 5-12) in some years. The combined losses of urban expansion, and long-term agricultural changes are 40,898 acres and would not change the current condition, but during drought years, the additional 1,286,525 acres of temporary impacts to conditional habitat brings the total impacted acres to 1,332,774 (47% of the suitable acres) and reduces suitable habitat acres to less than 2,000,000. Under scenario 2, these habitat losses/impacts would change the condition category to fair for available habitat in this analysis area, because the combined losses of urban expansion, long-term agricultural changes, and intensive use of conditional habitat reduce suitable habitat acres to less than 2,000,000, but greater than 1,000,000 (see Table 4-4and 5-12). Not all of the land use changes are likely to occur in suitable habitat, so the actual impacts are likely to be less than the percentages described above.

<u>Protected Areas-</u> There are 133,196 acres of managed, 52,114 acres of multi-purpose and about 43,000 acres of tribal protected lands. Protected areas include federal, state, tribal and private areas and many are known to support ABBs, (see Table 4-2 Protected Lands). The ABB is known to occur at several wildlife management areas, and a large TNC prairie preserve. Protection for these areas is likely to continue through 2099 and beyond. ABB habitat on these lands would not be managed directly for ABBs, but management for other species would maintain habitat conditions in the future under this scenario (see Table 5-12).

<u>Relative Abundance -</u> This analysis area has a relatively low ratio of positive to negative surveys with relatively large fluctuations between years. Reports for 2016 indicate more positive surveys and a higher ratio of positives. See Figure 4-12 for the last 15 year time frame, and Table 4-3. Trends at the Tall Grass Prairie Preserve and surrounding areas have demonstrated strong fluctuations, but with good recoveries over the last 10 years. Future land use changes are not expected to change the survey ratios or relative abundance. Current and future ratios of positive to negative surveys are rated as poor (see Table 5-12).

Population Distribution - The Distribution is currently fair with some recent positive surveys in the southern 2/3 of the analysis area and one concentration of positive surveys. The survey effort in portions of this analysis area is limited (see Figure 4-12). Future distribution would be expected to be similar to existing distributions but could improve with more surveys (see Table 5-12).

Summary of Land Use Effects on the Flint Hills Analysis Area -There are minor changes, relative to the existing conditions (see tables 4-5 and 5-12), anticipated in condition categories for future habitat factors, but no change in the overall resiliency for the Flint Hills Analysis Area under scenario 2 (land use changes alone). There are no large urban areas in this analysis area and any changes in rural land uses are expected to be relatively minor. This analysis area is on the western edge of the ABB range, has relatively low ratios of positive to negative surveys, and some portions may be relatively marginal habitat due to poor soils and limited precipitation. Continued management/protection on some large blocks of higher quality habitat/protected lands may be important in maintaining ABB population resiliency in this analysis area.

Table 5-12. Future resiliency of Flint Hills Analysis Area based on projected habitat and population factors under scenario 2 out to 2099.

Flint Hills Analysis Area					
SCENARIO 2 - Increased Rates of Land Change and Low Protection/Management					
	Future Habitat Factors		Future Population Factors		
CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
MODERATE	Fair	Good	Poor	Fair	MODERATE
See Chapter 4 for narrative	Still large enough to maintain ABB population, but suitable habitat reduces to less than 2 million acres during dry years.	Over 200,000 acres of protected lands, most with documented ABB presence.	This area has a low relative abundance and is expected to remain in this condition	No significant changes to population distrubutions anticipated in this area.	Higher rates of land use change and low protection and management is not expected to change the resiliency of ABBs within this analysis area.

Northern Analysis Areas

Loess Canyons Analysis Area

Habitat- There are 2,759,065 total acres and 1,678,054 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1), which is a small area relative to other analysis areas. Of the total analysis area, favorable habitat comprises 29.7%, conditional habitat 30.8%, marginal habitat 0.3% and unsuitable is 38.8%. Conditional habitat is 30.8% of the total area, but conditional habitats in northern analysis areas are less affected by grazing. Grazing is the primary land use on most of the existing suitable ABB habitat and grazing does not appear to negatively affect habitat suitability in northern analysis areas like it does in southern areas. Conversion of grasslands to cropland is a future threat to suitable habitat. Based on the potential rates of conversion, we expect a 30% percent net increase in cropland (246,920 acres) by 2099 under scenario 2. Urban expansion (20% net increase) is expected to impact 13,538 acres. The combined losses of urban expansion, and long-term agricultural changes (260,458 acres) are 15.5% of the suitable acres and do not reduce suitable habitat acres to less than 1,000,000. However, without active grassland management and prescribed fire, large areas of suitable habitat (at least another 30% or 503,416 acres, of the current suitable acres by 2099) are predicted to be impacted by dense stands of invasive red cedar and this habitat condition is unfavorable for ABBs and carrion sources (Walker and Hoback 2007, pages 297-298). The combination of cedar invasion, conversion of grassland to cropland, urban expansion and other land use changes is predicted to reduce suitable habitat to less than 1,000,000 acres in this relatively small analysis area. Land use changes under this scenario would change the condition to poor for available habitat in this analysis area (see Table 5-13).

Protected Areas – There are 15,342 acres of managed and 3,843 acres of multi-purpose protected lands. This area and percentage of protected lands is very low relative to most analysis areas. Protected areas are known to support ABBs, (see Table 4-2 Protected Lands). ABB habitat on these lands would not be managed for ABBs, but management for other species may indirectly maintain habitat conditions in some areas under this scenario. Relatively few areas are managed for ABBs currently so the current condition of poor is likely to continue under scenario 2 land use changes.

Relative Abundance - This analysis area has a fair ratio of positive to negative surveys (29.8%, See Figure 4-12 for the last 15 year time frame, and Table 4-3). Trends in survey ratios have demonstrated fluctuations with declines during droughts, but with good recoveries over the last 10 years in normal to wet years. Future land use changes are expected to change relative abundance in most areas under scenario 2. Relatively large areas of suitable habitat will become unfavorable through 2099 under scenario 2 land use changes. Suitable habitat in portions of the Loess Canyons Analysis Area would become more fragmented and reduce the ratio of positive to negative surveys.

Population Distribution - The distribution is currently fair with one relatively large contiguous concentration of positive surveys in the center of the analysis area (see Figure 4-12). The future distribution would be expected to become more fragmented due to red cedar invasion and conversions of grassland to croplands in some locations, but remain fair-poor by 2099.

Summary of Land Use Effects on the Loess Canyons Analysis Area - The current resiliency of the analysis area is considered moderate due to the fair habitat availability and area of native habitat, fair distribution, and fair ratios of positive to negative surveys (compared to other analysis areas, see Table 4-3). There are no large urban areas in this analysis area and any changes in rural land uses are expected to allow sufficient areas of suitable habitat to maintain ABB populations. However, future land use under scenario 2 includes low levels of protection and management for ABBs and habitat. Without active grassland management and prescribed fire, large areas of suitable habitat are expected to be impacted by dense stands of invasive red cedar and this habitat condition is unfavorable for ABBs and carrion sources (Walker and Hoback 2007, pages 297-298). The combination of cedar invasion, conversion of grassland to cropland, and other land use changes is predicted to reduce suitable habitat to less than 1,000,000 acres. The area is also sensitive to droughts because most of it does not have the high water table like the Sandhills to maintain soil moisture. ABB populations appear to fall to low numbers (low catch rates) during extended droughts in the Loess Canyons and this population is isolated from other populations (see Table 4-5 and 5-13). Declining conditions, (from moderate to low) are anticipated for future resiliency under scenario 2 for land use changes alone.

Table 5-13. Future resiliency of Loess Canyons Analysis Area based on projected habitat and population factors under scenario 2 out to 2099.

Loess Canyons Analysis Area					
SCENARIO 2 - Increased Rates of Land Change and Low Protection/Management					
	Future Habitat Factors		Future Population Factors		
CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
MODERATE	Poor	Poor	Poor	Fair	Low
See Chapter 4 for narrative	Suitable ABB habitat would decline due to expansion of invasive red cedar and conversion of grassland to row crop land use	Less than 20,000 acres of protected lands; future protection and management is considered poor relative to other areas.	Fair ratio of positive to negative surveys but drought and habitat impacts would affect relative abundance in the future.	One relatively large concentration which may change due to future land use.	Higher rates of land use change with low protection and management is expected to change the resiliency of ABBs within this analysis area.

Sandhills Analysis Area

Habitat - There are 10,819,170 total acres and 8,633,685 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1). Of the total analysis area, favorable habitat comprises 9.9%, conditional habitat 69.7%, marginal habitat 0.2% and unsuitable is 20.2%. This analysis area has the second largest area of suitable habitat of the seven analysis areas. Conditional habitat is nearly 70% of the total area, but conditional habitat in northern analysis areas are less affected by grazing or mowing. Grazing is the primary land use on most of the existing suitable ABB habitat and grazing does not appear to have the same negative affect on habitat suitability in northern analysis areas as it does in southern areas (see section 3.1). Conversion of grasslands to cropland is a future threat to suitable habitat. Based on the rates of conversion in past years, we expect a 30% percent net increase in cropland (430,255 acres) by 2099 under this scenario. Urban expansion (20% net increase) is expected to impact 24,850 acres by 2099. This would not change the resiliency condition of good for available habitat in this analysis area, because the combined losses of urban expansion and long-term agricultural changes (455,105 acres) are 5.3% of the suitable acres and do not reduce suitable habitat acres to less than 2,000,000 (see Table 5.3). Not all of the land use changes are likely to occur in suitable habitat so the actual impacts are likely to be less than the percentages described above.

Protected Areas – There are 393,983 acres of managed and 24,633 acres of multi-purpose protected lands in this analysis area. Protected areas are known to support ABBs, (see Table 4-2 Protected Lands), but some large areas of state and federal forest lands have very low catch rates for ABBs. The Valentine National Wildlife Refuge is the only large block of protected lands in this analysis area with relatively good numbers of ABBs, but smaller protected areas near the Niobrara River also have ABBs (W. Hoback, Oklahoma State University, pers. comm., January 22, 2018). ABB habitat on these lands would not be managed for ABBs, but management for other species may indirectly maintain habitat conditions in some areas under this scenario. Relatively few areas are managed for ABBs, so the current condition of good is likely to continue under scenario 2 land use changes.

Relative Abundance - This analysis area has the highest ratio of positive to negative surveys. See Figure 4-12 for the last 15 year time frame, and Table 4-3. Trends have demonstrated fluctuations, but with good recoveries over the last 10 years. Future land use changes under scenario 2 could have local effects, but are not expected to change the relative abundance condition of good for this analysis area.

Population Distribution - Distribution is currently good with some positive surveys in all portions of the analysis area and one large contiguous concentration of positive surveys (see Figure 4-12). The future distribution would be expected to become more fragmented due to conversions of grassland to croplands in some locations, but the overall distribution in the Sandhills Analysis Area would not be affected by future land use changes and should remain good by 2099. Expansion of wind farms in this analysis area could increase fragmentation and adversely affect future distribution.

Summary of Land Use Effects on the Sandhills Analysis Area - The Sandhills Analysis Area includes 10,819,170 total acres in northcentral portions of Nebraska. The current resiliency of the analysis area is considered high due to the large area of native habitat, good distribution, and high ratios of positive to negative surveys (compared to other analysis areas, see Table 4-3). The land use changes in scenario 2 may have some local impacts, but appear to be relatively minor in this large analysis area. There are no changes, relative to the existing conditions (see Table 4-5 and 5-14), anticipated in condition categories for future habitat or population factors or resiliency under scenario 2 for land use changes alone. There are no large urban areas in this analysis area and any changes in rural land uses are expected to allow sufficient areas of suitable habitat (about 94% of existing) to maintain ABB populations and are not expected to change the resiliency of the Sandhills Analysis Area.

However, this assessment of land use effects is qualified by our limited ability to quantify some potential future effects. For example, uncommon increases in crop prices could increase incentives for conversion of grassland to row crops to levels beyond the assumptions used in this scenario. Also, recent development and potential expansion of wind energy projects could add to impacts from other land use changes. The construction of wind turbines, roads, and powerlines has direct permanent habitat impacts and fragments the remaining habitat. The operation of wind turbines also has potential for direct take through ABB collisions with the blades. The collisions of blades with birds and bats could increase the abundance of carcasses and attract ABBs to the area. Indirect effects include changes to potential carrion populations, carrion availability, and abundance of potential competing scavengers such as raccoons, opossums, coyotes, and crows. The combination of fragmented habitat and collision-related carcasses could attract more scavengers and increase competition with ABBs for carcasses. Another potential indirect effect is the increased potential for conversion of grassland to row crops, due to improved road access and available electrical power for running electric pumps for irrigation.

Future land use effects related to wind power development were not factored into scenario 2 because we did not have estimates of future development or total areas that may be affected by wind projects and there are no studies available to evaluate the actual effects of wind projects on ABBs. The current area of wind projects is relatively small, but we do not know what areas, or what percentage of the suitable habitat in the Sandhills or other Northern analysis areas may be affected by wind projects in future years.

Table 5-14. Future resiliency of Sandhills Analysis Area based on projected habitat and population factors under scenario 2 out to 2099.

Sand Hills Analysis Area					
SCENARIO 2 - Increased Rates of Land Change and Low Protection/Management					
	Future Habitat Factors		Future Population Factors		
CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
HIGH	Good	Good	Good	Good	HIGH
See Chapter 4 for narrative	2nd largest analysis area; although much of the ABB habitat is conditional and vulnerable to land use change, remaining suitable habitat after projected changes remains good.	Over 400,000 acres of protected areas which are not expected to decline as a result of projected land use change.	Highest abundance of all analysis areas, which is not expected to change significanly as a result of land use change.	Positive surveys spread throughout the analysis area with no fragmentation, which is not expected to be significantly affecte by future land use.	Higher rates of land use change and low protection and management is not expected to change the resiliency of ABBs within this analysis area.

<u>*Niobrara River Analysis Area*</u>

<u>Habitat -</u> There are 4,108,903 total acres and 2,961,469 suitable acres (combined favorable, conditional and marginal land cover types, see Table 4-1). This is a medium sized area relative to other analysis areas. Of the total analysis area, favorable habitat comprises 6.4%, conditional habitat 65.3%, marginal habitat 0.4% and unsuitable is 27.9%. Grazing is the primary land use on most of the existing suitable ABB habitat and grazing does not appear to have the same negative affect on habitat suitability in northern analysis areas as it does in southern areas. Conversion of grasslands to cropland is a future threat to suitable habitat. Conversion of grasslands to cropland is a future threat to suitable habitat. Based on the rates of conversion in past years, we expect a 30% percent net increase in cropland (163,237.5 acres) by 2099. Urban expansion (20% net increase) is expected to impact 13,340 acres by 2099. This would not change the condition of good for available habitat in this analysis area, because the combined losses of urban expansion and long-term agricultural changes (net change of 176,578 acres) are 6% of the suitable acres and do not reduce suitable habitat acres to less than 2,000,000. Not all of the land use changes are likely to occur in suitable habitat so the actual impacts are likely to be less than the percentages described above. This would represent a worst case level of habitat effects related to changes in land use and the results are presented in Table 5-15.

<u>Protected Areas</u> – This analysis area includes 58,918 acres of managed, 33,582 acres of multi-purpose protected lands and a large area of tribal land. (see Table 4-2 Protected Lands). ABB habitat on these lands would not be managed for ABBs, but management for other species may indirectly maintain habitat conditions in some areas under this scenario. Relatively few areas are managed for ABBs so the current condition of poor is likely to continue under scenario 2 land use changes.

Relative Abundance - This analysis area has a fair ratio of positive to negative surveys (30.7) and the second highest percentage of positive surveys relative to other western analysis areas. See Figure 4-12 for the last 15 year time frame, and Table 4-3. Trends have demonstrated fluctuations, but with good recoveries over the last 10 years. Future land use changes under scenario 2 could have local effects, but are not expected to change the relative abundance condition (fair) for the analysis area.

Population Distribution – The distribution is currently fair with some positive surveys in all portions of the analysis area and one contiguous concentration of positive surveys (see Figure 4-12). The future distribution would be expected to become more fragmented due to conversions of grassland to croplands in some locations, but the overall distribution and concentrations in the Niobrara River Analysis Area under scenario 2 land use changes should remain fair by 2099.

Summary of Land Use Effects on the Niobrara River Analysis Area - The Niobrara River Analysis Area includes 4,108,903 total acres in northcentral portions of Nebraska and southcentral portions of South Dakota. The current resiliency of the analysis area is considered moderate due to the moderate area of native habitat, relatively good distribution, and fair ratios of positive to negative surveys (compared to other analysis areas, see Table 4-3). The land use changes in scenario 2 may have some local impacts with a loss of about 6% of current suitable habitat in this analysis area. There are no changes, relative to the existing conditions (see Table 4-5 and 5-15), anticipated in condition categories for future habitat or population factors or resiliency under scenario 2 for land use changes alone. There are no large urban areas in this analysis area and any changes in rural land uses are expected to allow sufficient areas of suitable habitat (about 94% of existing) to maintain ABB populations and are not expected to change the resiliency of the Niobrara River Analysis Area. However, a 6% loss of habitat in this analysis area could be a significant impact if it increases fragmentation in this relatively small analysis area. The remaining suitable habitat is only slightly above 2,500,000 acres and any new or additional impacts, combined with the scenario 2 habitat losses could affect future habitat condition factors and possibly resiliency in this analysis area.

Table 5-15. Future resiliency of Niobrara River Analysis Area based on projected habitat and population factors under scenario 2 out to 2099.

Niobrara River Analysis Area					
SCENARIO 2 - Increased Rates of Land Change and Low Protection/Management					
	Future Habitat Factors		Future Population Factors		
CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
MODERATE	Good	Poor	Fair	Fair	MODERATE
See Chapter 4 for narrative	Much of the ABB habitat is conditional and vulnerable to land use change. Suitable habitat after projected changes remains good, but is close to fair level.	Over 90,000 acres of protected lands, but no lands being managed specifically for ABBs. This condition is not expected to change.	Abundace is not expected to change significanltly as a result of future land use changes.	Future conditions may become more fragmented due to land conversions, but should remain in fair condition.	Future land use is not expected to change the resiliency, but this could change with even minor additional impacts.

New England Analysis Areas

The New England Analysis Area consists of two islands where ABB are known to occur: Block Island, RI and Nantucket, MA. The current resiliency of the analysis area is considered moderate due to the limited area of potential habitat, relatively good distribution, and moderate ratios of positive to negative surveys (compared to other analysis areas, see Table 4-3).

Habitat - Land use changes and effects to ABBs are predicted to be relatively minor through 2099 because about 54% of the existing suitable habitat is protected. No conversion to cropland is expected in this analysis area and the only anticipated habitat impacts due to land uses is a 30% net increase in urban acres relative to existing conditions (see discussion in section 5.2.1.2). Urban expansion is expected to impact about 488 additional acres on Block Island (out of 6,111 acres) and 656 additional acres on Nantucket Island (out of 36,321 acres) by 2099 under scenario 2. The combination of urban expansion and no management reduce the habitat condition somewhat under scenario 2, but the habitat availability was already considered poor due to the limited area on the islands (less than 1,000,000 acres). The impacts of urban expansion are significant at Block Island, in that urban areas are expected to occupy about 2,115 acres of a 6,111 acre island, but minor relative to the effects of no management. The habitat condition is considered poor under scenario 2 (Table 5-16).

Protected Areas – The impacts due to urban expansion are anticipated to be partially offset by increases in protected lands. Block Island is 6,111 acres in size, and has a large area of conservation lands (2,523 acres; 41%). Nantucket, 36,321 acres in size, is similar, with a large proportion held by land trusts or other protected status (11,934 acres; 33%). Combined there is a total of 42,431 acres with 25,865 suitable habitat acres and 14,457 acres of protected lands. The areas of protected lands are not expected to change under scenario 2 and most of the protection is not specifically related to the ABB. The condition for protected areas is considered poor due to the limited area on the islands (less than 100,000 acres), but the percentage of protected lands for the New England Analysis Area is higher than all other analysis areas and does help protect habitat into the future. The high percentage of protected lands improves the resiliency of this analysis area.

Relative Abundance – Relative abundance is expected to be poor under scenario 2. The relative abundance appears to be related to the level of carcass provisioning and this management practice would be discontinued under scenario 2. The ABB population on Nantucket is not expected to survive with no management (Mckenna-Foster et al. 2016, p. 7) and the relative abundance for Block Island is expected to decline without active management.

Population Distribution – The future distribution of ABBs on Nantucket Island is expected to be zero and this reintroduced population is expected to fail without continued carcass provisioning (Mckenna-Foster et al. 2016, p. 7). Distribution on Block Island is expected to be similar to the existing distribution and considered fair.

Summary of Land Use Effect on the New England Analysis Area - The current resiliency (moderate) is largely due to the active management (especially on Nantucket Island) and reducing or eliminating the active management is likely to reduce the abundance of ABBs on Block Island and cause the extirpation of ABBs on Nantucket Island. Future resiliency is expected to be low. We are basing these assumptions on monitoring in recent years that has documented reductions in New England ABB populations with reduced management and reduced supplementation of carcasses.

Table 5-16. Future resiliency of the New England Analysis Area based on projected habitat and population factors under scenario 2 out to 2099.

New England Analysis Area					
SCENARIO 2 - Increased Rates of Land Change and Low Protection/Management					
	Future Habitat Factors		Future Population Factors		
CURRENT Resiliency	Available Habitat	Protected Areas & Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
MODERATE	Poor	Poor	Poor	Fair	LOW
See Chapter 4 for narrative	Both islands have less than 30,000 acres of suitable habitat, and impacts from future land use change is expected to be relatively minor	Nearly 14,000 acres of protected lands between both islands with effective species management. Not expected to change.	Relative abundance declines without management/provisioning, with only minor effects from future land use change.	Distribution remains fair on Block Island, but ABBs are extirpated on Nantucket with no management. Minor effects from future land use change.	Future land use has a minor effect but no management reduces the resiliency in this analysis area.

Summary of Land Use Change Effects on Resiliency for Scenario 2

Southern Plains Analysis Areas – There are no changes (Table 5-17) anticipated in resiliency under scenario 2 for land use changes alone. There are some urban areas in the Southern Plains analysis area, but they are not near areas of ABB concentrations or the concentrations near urban areas are on protected lands that would not be affected by urban expansion. Some land uses such as oil and gas development can have local impacts, but are expected to affect less than 1% of the suitable habitat in southern analysis areas as a whole. Most of these analysis areas are rural and any changes in rural land uses are expected to have a relatively minor effect on ABB populations under scenario 2. The large areas of known and potential habitat in the Southern Plains tend to buffer the effects of most land use changes such as urban and cropland expansion when these changes affect such a low percentage of the suitable habitat. There is a projected combined permanent loss of 1.2% or 246,293 acres from the existing 19,995,088 acres of suitable habitat for the Southern Plains analysis areas. Our assumptions for land use changes were made to be within a potentially plausible range, but even if those percentages were increased, and the permanent loss was multiplied by 10, the losses would only amount to about 12 percent of the suitable habitat. However, some relatively large areas of suitable habitat appear to have low ratios of positive to negative surveys and land uses may make some areas relatively marginal and reduce relative abundance. Intentional management for ABBs is very limited, except on ABB conservation banks and the lack of management under scenario 2 has very little effect in the Southern Plains analysis areas.

Northern Plains Analysis Areas - There are no changes (Table 5-17) anticipated in condition categories for future habitat, population factors or resiliency under scenario 2 for land use changes alone in the Sandhills or Niobrara River Analysis Areas, but there are changes in the Loess Canyons Analysis Area. The combined impacts of urban expansion and conversion to cropland are expected to affect about 15 % of the suitable habitat and an additional 30% habitat loss (due to redcedar expansion) is expected in the Loess Canyon Analysis Area. Habitat losses due to land use changes are projected to be 5-6% in the rest of the Northern Plains Analysis Areas. Not all of the land use changes are likely to occur in suitable habitat so the actual impacts are likely to be less than the percentages described above. Most of these analysis areas are rural and changes in rural land uses are expected to have mostly negative effects, but should allow sufficient areas of suitable habitat to maintain ABB populations in most analysis areas. The projected land use changes have a greater effect on smaller analysis areas and reduce the resiliency of the Loess Canyons Analysis Area, but not the other Northern Plains analysis areas. The lack of management under scenario 2 affects the habitat availability in the Loess Canyons Analysis Area. The lack of management through brush control or prescribed fire under scenario 2 allows for expansion of red cedar in the Loess Canyons Analysis Area and greatly contributes to future declines in habitat and resiliency for the ABBs in this area. Scenario 2 land use changes are relatively close to affecting habitat availability factors for the Niobrara River and any new or additional impacts, combined with the scenario 2 habitat losses, could potentially reduce suitable habitat to less than 2,000,000 acres and affect future habitat condition factors in this analysis area.

This assessment of land use effects includes cautions due to our limited ability to quantify some potential future effects. For example, uncommon increases in crop prices could increase incentives for conversion of grassland to row crops to levels beyond the assumptions used in this scenario. Also, recent development and potential expansion of wind energy projects could add to impacts from other land use changes. The construction of wind turbines, roads, and powerlines has direct permanent habitat impacts and fragments the remaining habitat. The operation of wind turbines also has potential for direct take through ABB collisions with the blades. The collisions of blades with birds and bats could increase the abundance of carcasses and attract ABBs to the area. Indirect effects include changes to potential carrion populations, carrion availability, and abundance of potential competing scavengers such as skunks, raccoons, opossums, coyotes, and crows. The combination of fragmented habitat and collision-related carcasses could attract more scavengers and increase competition with ABBs for carcasses. Another potential indirect effect is the increased potential for conversion of grassland to row crops due to improved road access and available electrical power lines for running electric pumps for irrigation.

Future land use effects related to wind power were not factored into scenario 2 because we did not have estimates of future development or total areas that may be affected by wind projects and there are no studies available to evaluate the actual effects of wind projects on ABBs. The current area of wind projects is relatively small and there are 6,471 wind turbines registered in the Northern Plains Analysis Areas, but we do not know what areas, or what percentage of the suitable habitat in Northern Plains analysis areas may be affected by wind projects in future years.

New England Analysis Areas – The future urban expansion reduces the habitat conditions somewhat under scenario 2, but the habitat availability was already considered poor due to the limited area on the islands (less than 1,000,000 acres). The impacts of urban expansion are significant at Block Island, in that urban areas are expected to occupy about 2,115 acres of a 6,111 acre island, but are minor relative to the effects of no management. Future resiliency would be expected to be fair with land use changes alone, but is considered poor without continued carcass provisioning. The current resiliency (moderate) is largely due to the active management (especially on Nantucket Island) and reducing or eliminating the active management is likely to reduce the abundance of ABBs on Block Island and cause the extirpation of ABBs on Nantucket Island. Condition categories for future population factors and resiliency are reduced under scenario 2 due to a lack of active management (Table 5-17).

Table 5-17. Current and Future resiliency of American burying beetle analysis areas based on future habitat and population factors under Scenario 2.

Scenario 2 - Increased Rates of Land Change and Low Protection/Management							
		Future Habitat Factors			Future Population Factors		
Analysis Area	CURRENT Resiliency	Combined (Urban and Long-Term Agriculture) Land Changes* (acres)	Available Habitat	Protected Areas/ Management	Relative Abundance	Population Distribution	FUTURE Habitat/Population Resiliency
Northern Plains							
Niobrara River	**Moderate**	-901,781	Good	Poor	Fair	Fair	**Moderate**
Sand Hills	**High**	-2,614,956	Good	Good	Good	Good	**High**
Loess Canyons	**Moderate**	-1,020,370	Poor	Poor	Poor	Fair	**Low**
Southern Plains							
Flint Hills	**Moderate**	-134,596	Fair	Good	Poor	Fair	**Moderate**
Arkansas River	**High**	-229,284	Good	Good	Fair	Good	**High**
Red River	**Low**	-80,145	Good-Fair	Fair	Poor	Poor	**Low**
New England							
New England	**Moderate**	-1,142	Poor	Poor	Poor	Fair	**Low**

*does not include temporary changes to conditional habitat

5.3.2.2 Representation

Under Scenario 2, the breadth of genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the species' range could be reduced with accelerated levels of land use changes and no management. The relative abundance and resiliency of the New England populations will be reduced and the genetic diversity represented by this analysis area is at much greater risk. The population on

Block Island would have low resiliency and Nantucket Island would no longer support ABBs without continued management. The genetics of New England ABBs appears to be unique and may be the only remaining representation of eastern ABB populations.

5.3.2.3 Redundancy

For the ABB, we are using the number and geographic distribution of populations (measured through survey data) and of occupied and potentially suitable habitat, as described by survey data and geospatial analyses, to measure redundancy. Current redundancy is 8-9 ‘populations’, three in the Southern Plains (Arkansas River, Red River, and Flint Hills), three in the Northern Plains (Niobrara, Sandhills, and Loess Canyons), two within the New England Analysis Area (Block Island and Nantucket) and one reintroduction in Missouri. Redundancy for this scenario would be reduced from current conditions with the loss of at least one New England island population by 2099. The Nantucket Island population is dependent on active management and will most likely not be self-sustaining under scenario 2. The Missouri reintroduction appears to be successful, but it is too early to tell if this reintroduction will be self-sustaining over any length of time without active management. The future redundancy also could be reduced if the Loess Canyons population is extirpated due low resiliency, and the Red River population continues to decline and does not recover. The future redundancy would be reduced to 7 populations under scenario 2 with the loss of the reintroduced populations at Nantucket Island and Missouri. The redundancy could possibly be reduced to 4, if the Red River population continues to decline, Loess Canyons population is extirpated, and 3 sites with active management (both the New England populations and the Missouri reintroduction) cannot maintain themselves without active management.

5.3.2.4 Summary of Viability for Scenario 2

The changes in land use do increase losses of suitable habitat, but most analysis areas in the Northern and Southern Plains are large enough that the potential losses impact a small percentage of the suitable habitat. The losses of habitat do affect resiliency (using current criteria) in Loess Canyons and New England Analysis Areas, primarily because they are smaller analysis areas. The scenarios lack of management for ABBs has relatively little impact in the Northern and Southern Plains because few areas currently have active management for ABBs. The exceptions to this would be the Loess Canyons and New England populations and all reintroduction sites that are currently managed for ABBs. The lack of active management could reduce the resiliency of ABB populations at these sites and the resiliency of the Red River, Loess Canyons and New England Analysis Areas are expected to be low under scenario 2. The lack of management can affect habitat suitability and the Loess Canyons is affected by red cedar expansion without some form of mechanical brush control or prescribed fire. No management can also affect the species more directly and without active monitoring and continued carcass provisioning, the New England populations are at risk. The Nantucket Island population is dependent on active management (Mckenna-Foster et al. 2016, p. 7) and will most likely not be self-sustaining under scenario 2. The Block Island population may be less dependent on carcass provisioning, but is likely to decline without management and the future resiliency of the New England Analysis Area is considered low. The Missouri reintroduction appears to be successful, but it is too early to tell if this reintroduction will be self-sustaining over any length of time without active management.

The viability of the ABB is reduced under scenario 2 (relative to the current status) with resiliency in the New England and Loess Canyons analysis areas changing from moderate to low (see Table 5-17). The potential success of reintroductions is also reduced or eliminated under a scenario with no active management. The status under scenario 2 includes two large populations with high resiliency (Arkansas River and Sand Hills Analysis Areas), two with moderate resiliency (Flint Hills and Niobrara River Analysis Areas) and three populations with low resiliency (Red River, Loess Canyons, and New England Analysis Areas). Representation and redundancy are both reduced under scenario 2 with potential losses of populations in New England, Loess Canyons, Red River, and the reintroduction site in Missouri (see Table 5-17).

5.4 CLIMATE CHANGE

Chapter 3 provides an overview of climate change science and how a changing climate may affect the ABB and its habitat and Chapter 4 discusses how climate change is currently affecting the species. In this chapter we assess climate change projections and how the ABB may be affected in the future.

5.4.1 Climate projection methods used for our analyses

The Intergovernmental Panel on Climate Change (IPCC) adopted four possible greenhouse gas emission scenarios in its fifth Assessment Report (Hartmann et al. 2013, Moss et al. 2008), which were designed to capture the range of effects of greenhouse gas emissions ranging from near-term recovery (within 100 years) to most probable worst case scenario, with two intermediate scenarios (Moss et al 2008). Each scenario represents total greenhouse gas emissions across the planet. These contributing chemicals included carbon dioxide, methane, nitrous oxide, ozone, other minor greenhouse gases, aerosols, chemically active gases, and land use/land cover.

The four Representative Concentration Pathways (RCP) scenarios (2.6, 4.5, 6, and 8.5) were designed to capture the possible ranges of climate change within the next century. In our analysis of potential climate change impacts to the American burying beetle and its habitat, we only considered two of those scenarios, RCP 4.5 and 8.5. Though those scenarios were originally published in 2006-2007 and the final document produced by the IPCC by 2008 (Moss et al.), by 2014 global temperature had already increased by 0.8°C (1.4°F, Chapter 4). This temperature increase coincided with CO_2 emissions in 2014 (projected, Fuss et al. 2014) of 37.0 Gt CO_2. The current rate of emissions change best corresponds to the predictions of the RCP 8.5 scenario and not the lower emission scenarios (Figure 5-3). Emissions pathways that will actually occur in the future are not known and will depend on national and international policy, technology development, and other socio-economic factors. This is why typically more than one scenario is typically considered – so that a range of plausible climate futures can be evaluated.

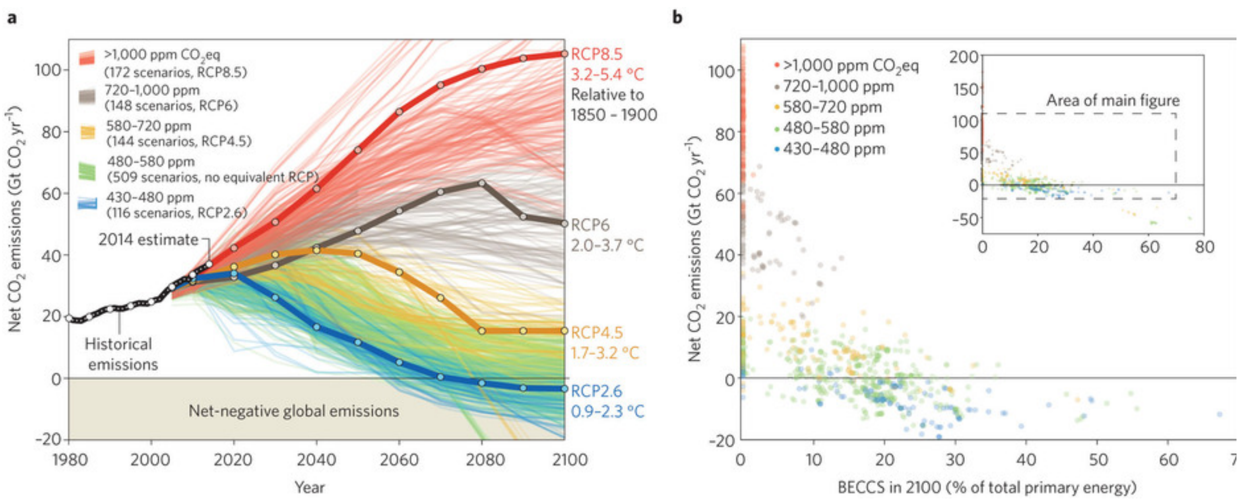


Figure 5-3. "**a**, Historical emissions from fossil fuel combustion and industry (black) are primarily from the Carbon Dioxide Information Analysis Center. They are compared with the IPCC fifth assessment report (AR5) Working Group 3 emissions scenarios (pale colors) and to the four representative concentration pathways (RCPs) used to project climate change in the IPCC Working Group 1 contribution to AR5 (dark colors). **b**, The emission scenarios have been grouped into five climate categories measured in ppm CO_2 equivalent (CO_2eq) in 2100 from all components and linked to the most relevant RCP. The temperature increase (right of panel **a**) refers to the warming in the late twenty-first century (2081–2100 average) relative to the 1850–1900 average. Only scenarios assigned to climate categories are shown (1,089 of 1,184). Most scenarios that keep climate warming below 2 °C above pre-industrial levels use BECCS and many require net negative emissions (that is, BECCS exceeding fossil fuel emissions) in 2100. Data sources: IPCC AR5 database, Global Carbon Project and Carbon Dioxide Information Analysis Center." (excerpt: Fuss et al 2014)

Additionally, the analytical logistics of modeling all four scenarios resulted in our selection of only two scenarios for our analysis. The Coupled Model Intercomparison Project Phase 5 (CMIP5, http://cmip-pcmdi.llnl.gov/cmip5/) is the agency tasked with soliciting modeling groups and collecting results of global climate models based on the RCP scenarios. The CMIP5 only required modeling groups to produce climate model outputs for the RCP 4.5 and RCP 8.5 scenarios to be included in the final project. It was for this reason that many of the modeling groups included in the CMIP5 did not even run RCP 2.6 or RCP 6.0 models. The statistically downscaled climate models used in the analyses presented here were designed so that a there was a large enough and constant set of models and variables for downscaling. The Multivariate Adaptive Constructed Analogs (MACA) modeling team was able to get a consistent set of 20 models with two scenarios for a suite of seven climate variables by only using those two, rather than three or four, scenarios (K. Hegewisch, personal communication, September 19, 2016).

All data and model values used for climatic analyses were obtained from publicly available sources. Historical climate data from the years 1981 through 2010 (including 30 year normal and yearly data) for temperature and precipitation variables were obtained from PRISM (PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 4 Feb 2004). All other climate data, both historical (1971 through 2000) and predictions were obtained from the MACA Statistically Downscaled Climate Data from CMIP5 at the University of Idaho. Climate forcings in the MACAv2-METDATA were drawn from a statistical downscaling of global climate model (GCM) data from the Coupled Model Intercomparison Project 5 (CMIP5, Taylor et al. 2012) utilizing a modification (Hegewisch, Abatzoglou, in prep.) of the Multivariate Adaptive Constructed Analogs (MACA, Abatzoglou and Brown, 2012) method with the METDATA (Abatzoglou, 2011) observational dataset as training data. Historical data products (1971-2000) from the MACAv2 climate forcings do not represent the actual climate or weather during the historical period for any individual year because the data is derived from model predictions for those years. However, the MACAv2 climate forcings do have the same summary statistics as the actual historical data and only those summary statistics were used for this analysis.

The variability of the future temperature projections is analyzed by comparing the mean maximum air temperatures for June-August of all 20 models with the mean outcomes of the five models yielding the highest outcomes and the five yielding the lowest projected outcomes for all analysis areas. This comparison was made for both the RCP 4.5 and 8.5 levels of emissions and an example for the Shawnee site in the Arkansas River Analysis Area is represented by Figure 5-4 below. Similar graphs for all analysis areas are included in Appendix B. Climate change predictions were extracted from the larger prediction dataset to evaluate the best (coolest) and worst (warmest) case within each emissions scenario. For each point estimate location (Table 4-4) models were ranked based on the mean maximum summer (June, July, and August) for the entire prediction period. The five warmest and five coolest, based on the rankings, models for each location were then averaged for each year to create a warm model average and a cool model average. The individual models incorporated in the two extreme subsets differed between sites and emissions scenario (Appendix B).

The mean difference between the extreme groups was used in lieu of the 20 model mean to explore how the extremes within the temperature prediction dataset would affect the encroachment of temperatures unsuitable to the ABB within the current ABB range. The new temperature and range maps for the two extremes were approximated by changing the classification of temperature values on the original maps in the direction and magnitude of the mean variability of the relevant mean extreme for the three analysis areas within the northern or southern plains. This modification was accomplished for the warmer and cooler extremes within both RCP 4.5 and RCP 8.5. These maps are only approximations of the effects of the temperature prediction extremes on the encroachment of temperature thresholds, because the maps are only reclassifications of the 20 model mean predictions and not the actual 5 model means.

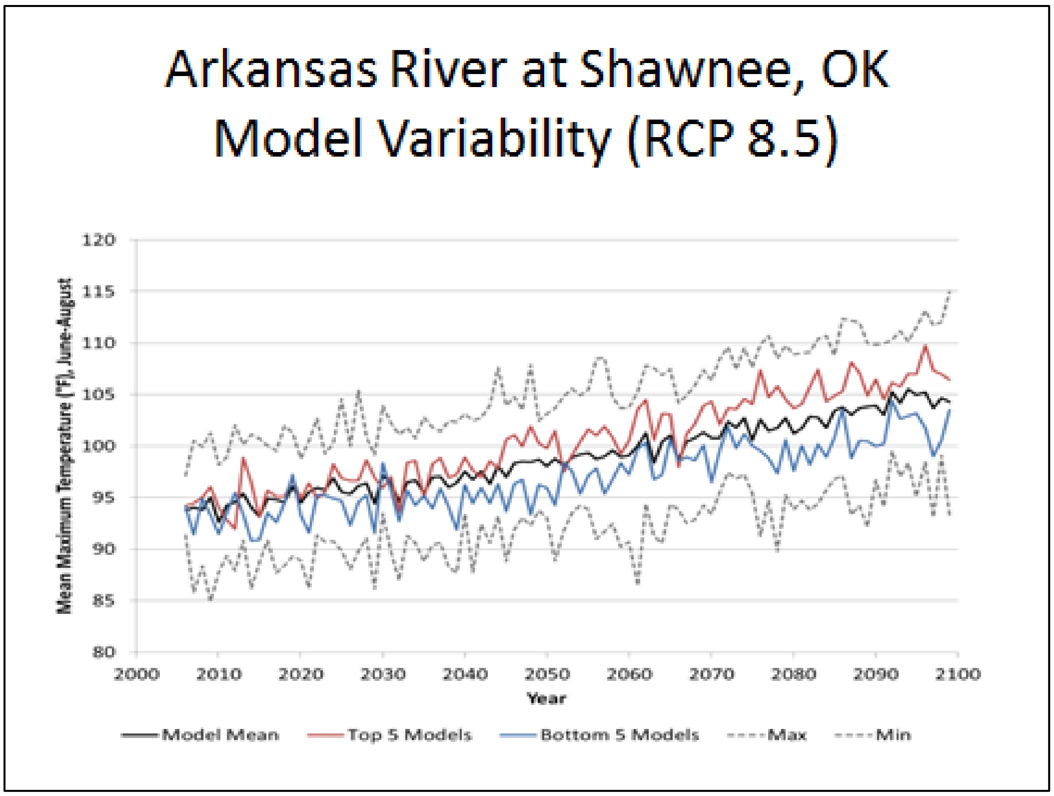


Figure 5-4. Example of variability of projections from different models. The solid black line is temperatures projected by the average for all 20 models; the red line is the average of the 5 highest (warmest) outcomes; the blue line is the average of the 5 lowest (coolest) outcomes, and the dashed lines are the highest and lowest individual outcomes. (Figures G-L, Tables 3-5)

5.4.1.1 Maximum Summer Temperature Threshold

The temperature effects on survival, activity and reproduction all have the potential to limit the ABB range and we are not certain what is the most limiting factor, but current and historic range conditions are assumed to represent those limitations. The Red River in southern Oklahoma/northern Texas represents the southern edge of the species' range and may represent the limits of maximum temperature conditions that can support ABBs.

The mean maximum air temperature for the Red River Area is 94.0 degrees F for the June-August, 1981-2010 time periods (Figure 5-4). The 2001-2015 mean maximum temperatures for areas near the Red River in July-August are 94-95 degrees F. We have few positive surveys in OK near this area since 2008 and no positive surveys in TX or AR near the Red River since 2008. We have no evidence to suggest that habitat conditions within this area has significantly changed, which might explain observed ABB declines in this area. Additionally, other portions of the ABB range have recovered from recent low numbers and 2016 appears to be a relatively good year for ABB catch rates in OK, but this southern edge of the range does not appear to be following that trend. It is possible that temperatures near the Red River area are at, or past a threshold that would support ABBs. This may be further supported by the fact that the species does not exist south of the Red River area, where habitat, soil conditions, and carrion availability are likely to be similar to the Red River area, leading us to believe that the southern edge of the species range is driven by this temperature or climate threshold. Historically relatively few documented ABB records are south of the Red River latitude and nearly all of these records are from coastal areas where temperatures would be moderated by the oceans. The historical mean maximum temperatures for these historical southern records near the coasts are not warmer, and in some cases cooler, than the Red River area (see Figure 5-5). The Red River area represents the warmest portion of the historical and current range and no positive ABB surveys have been documented south of this Red River analysis area latitude in over 70 years. There are no current or known historical populations of ABBS in areas with summer mean maximum temperatures that meet or exceed 95° F

Existing survey information from Ft. Chaffee (Arkansas River Analysis Area) supports the assumption that mean maximum temperatures above 95° F would adversely affect ABB populations. Monitoring of ABBs has occurred yearly from 1992 through 2016. During the sampling period, catch rates of ABBs declined from the previous year every time mean maximum temperatures exceed 95° F (N = 6). Based on this information, continued declines in catch rates and potential extirpation would be possible if mean maximum temperatures exceeding 95° F became the average during summer months and more extreme temperatures occurred more frequently. Additional discussion on ABB distributions along the southern edge of their range is found in section 3.8.2 and the Red River Analysis Area discussion in Section 4.4.2.

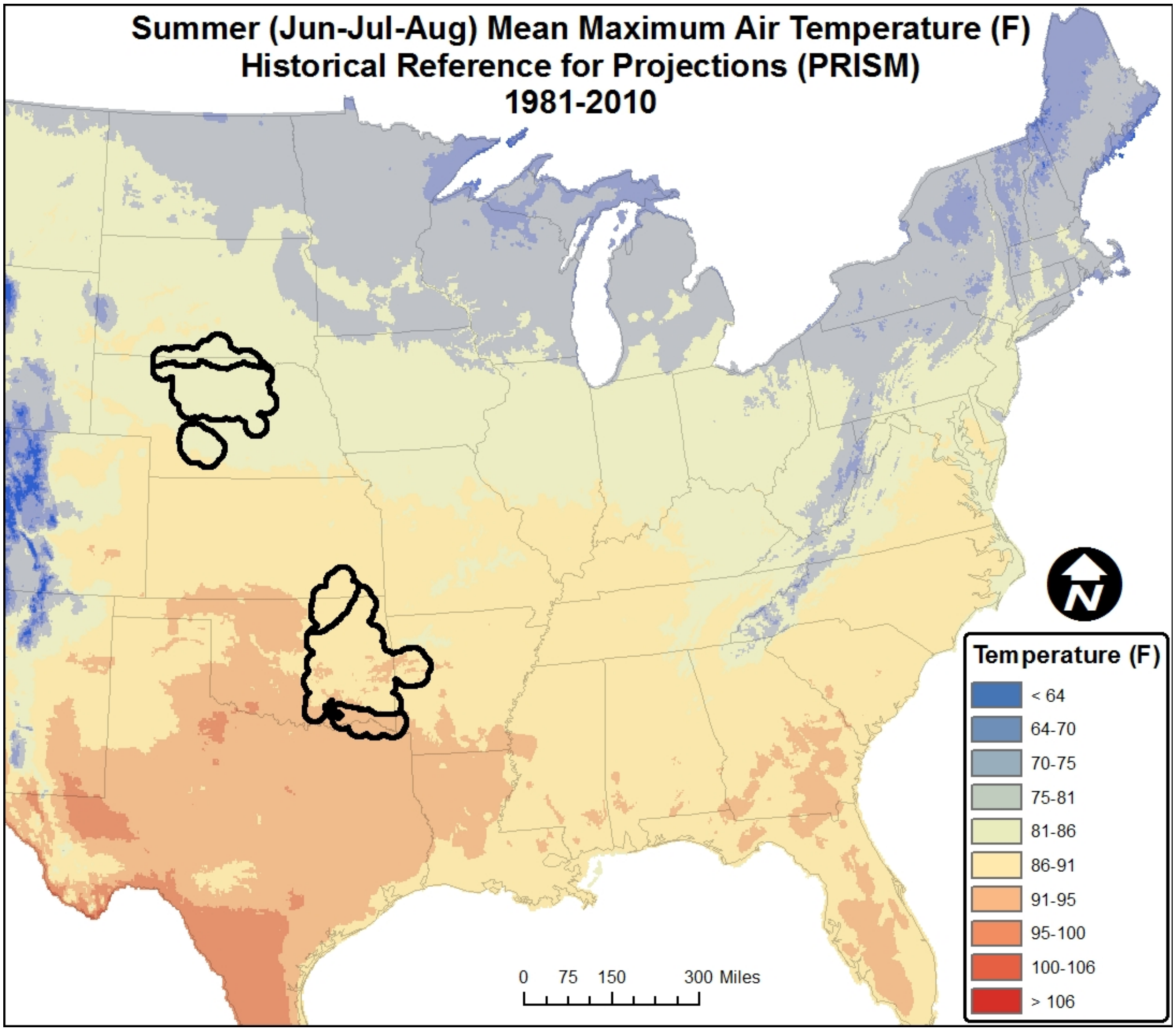


Figure 5-5. Mean maximum summer maximum air temperature (F) from 1981-2010. Data Source PRISM.

The taxonomy and life history of ABBs would indicate a limited ability to tolerate temperatures warmer than the 95 ° F threshold. Nicrophorus abundance and diversity are higher in cooler climates. There are no Nicrophorus species in tropical climates. Reasons for burying beetles' lack of success in southern locales include increased competition with ants, and flies, as well as increased rates of carcass decomposition. Carcass decomposition is dominated by dipteran species (true flies) and the diversity of dipteran species using carcasses increases in warmer climates. There are 15 species of Nicrophorus in the United States and Canada, but only 2 endemic to Central America and they occur at higher elevations. Based on species presence and existing climate conditions, few Nicrophorus species appear to be capable of maintaining populations in areas with average summer mean maximum temperatures exceeding the 95 ° F threshold (possibly N. carolinus, pustulatus and marginatus) and there are no Nicrophorus species in areas with average summer mean maximum temperatures exceeding 100 ° F.

Related to climate conditions, we recognize that precipitation, humidity, and soil moisture in combination with temperature influences ABB distribution and plan to assess those interactions, as well. But for the purpose of assessing the effects of climate changes on ABB population viability and habitat suitability, we are focusing on mean maximum temperatures during the summer months (Jun-Aug) to represent a threshold of all climate conditions that can support ABB populations. For evaluating the effects of future climate changes on the resiliency of all analysis areas, we are assuming a mean maximum temperature threshold of 95° F.

5.4.1.2 Nighttime Temperatures above 75 Degrees

Data analyses for climate predictions were similar to those employed for historical data (Chapter 4, Section 4.6). The metrics used were nights per year with temperatures above 75°F (likely no reproduction) and nights per year between 32°F and 60F (likely metabolically stressful with no aestivation and no foraging). Temperature data were collected using MACAv2-METDATA statistically downscaled CMIP5 climate predictions for minimum temperature (Abatzoglou, 2011 – entire; Abatzoglou and Brown, 2012 - entire). Data were collected from the same locations adjacent to cities used in Chapter 4. After the number of days for each year analyzed for each metric was calculated, those time-series for each location were explored using simple and natural log linear regression (Year was used to predict the natural log + 1 transformed day count). No trends or significant differences were observed for the metric measuring the number of nights between 32°F and 60°F for any analysis area. Geostatistical analyses were performed using ArcGIS (ArcMap version 10.3, ESRI 2011). All other analyses were performed using MS Excel (Microsoft Corporation, Redman, WA).

5.4.2 Resiliency under Future Climate Conditions

5.4.2.1 Maximum Summer Temperature Threshold

Our identification of temperature thresholds for the ABB are described in Section 5.4.1.1 above and summarized here. The temperature effects on survival, activity and reproduction all have potential limit the ABB range. The Red River in southern Oklahoma/northern Texas represents the recent southern edge of the species' range and may represent the limits of maximum temperature conditions that can support ABBs. The 2001-2015 mean maximum temperatures for areas near the Red River in July-August are 94-95 degrees F and represent current temperature conditions.

For the purpose of assessing the effects of climate changes on ABB population viability and habitat suitability, we are focusing on mean maximum temperatures during the summer months (Jun-Aug) to represent a threshold of all climate conditions that can support ABB populations.

ABB populations may be able to survive periodic or occasional years with mean maximum temperatures at or above 95° F, but areas that average mean maximum temperatures above 95° F are not likely to support populations. For evaluating the effects of future climate changes on the resiliency of all analysis areas, we are assuming a mean maximum temperature threshold of 95° F. Temperatures reported for the analysis areas below represent the mean temperature of a given 30 year time period for a given emissions scenario.

Because we do not have studies designed to determine ABB temperature threshold data, we understand that the temperature threshold could be a range of temperatures and that northern ABBs may have a lower threshold than southern ABBs that may have adapted to higher temperatures (see sections 3.8.2 and 4.6). Therefore, we have identified a near mean maximum threshold temperature range of 93-95° F for the northern analysis areas and 94-95° F for southern analysis areas. These near threshold temperatures represent climate conditions that could negatively affect the ABB's ability to feed, shelter, or reproduce, but for the purposes of our analysis, we are assuming that populations under these temperatures will remain viable. Below, we analyze these thresholds and other projected changes in climate (such as changes in precipitation) over the existing ABB range to assess potential impacts to ABBs within all analysis areas. Survival and reproductive climate thresholds are affected by a combination of temperature and moisture factors, but forecasting future effects of climate changes on temperature, precipitation and soil moisture is difficult. Only information on forecasted temperature and precipitation are presented in this report.

The effects of climate change and increasing temperatures (Figure 5-6) tends to make the effect of all other future risk factors irrelevant and results are different depending on the geographic location (Southern Plains, Northern Plains, and New England), which model is used (RCP 4.5 and 8.5), and how far into the future we assess the impact (2039, 2069 and 2099). The current observed rate of climate change is similar to the RCP 8.5 (high emissions scenario) models, but rates could change over the analyzed time periods. This is why we considered more than one scenario to evaluate a range of plausible climate futures.

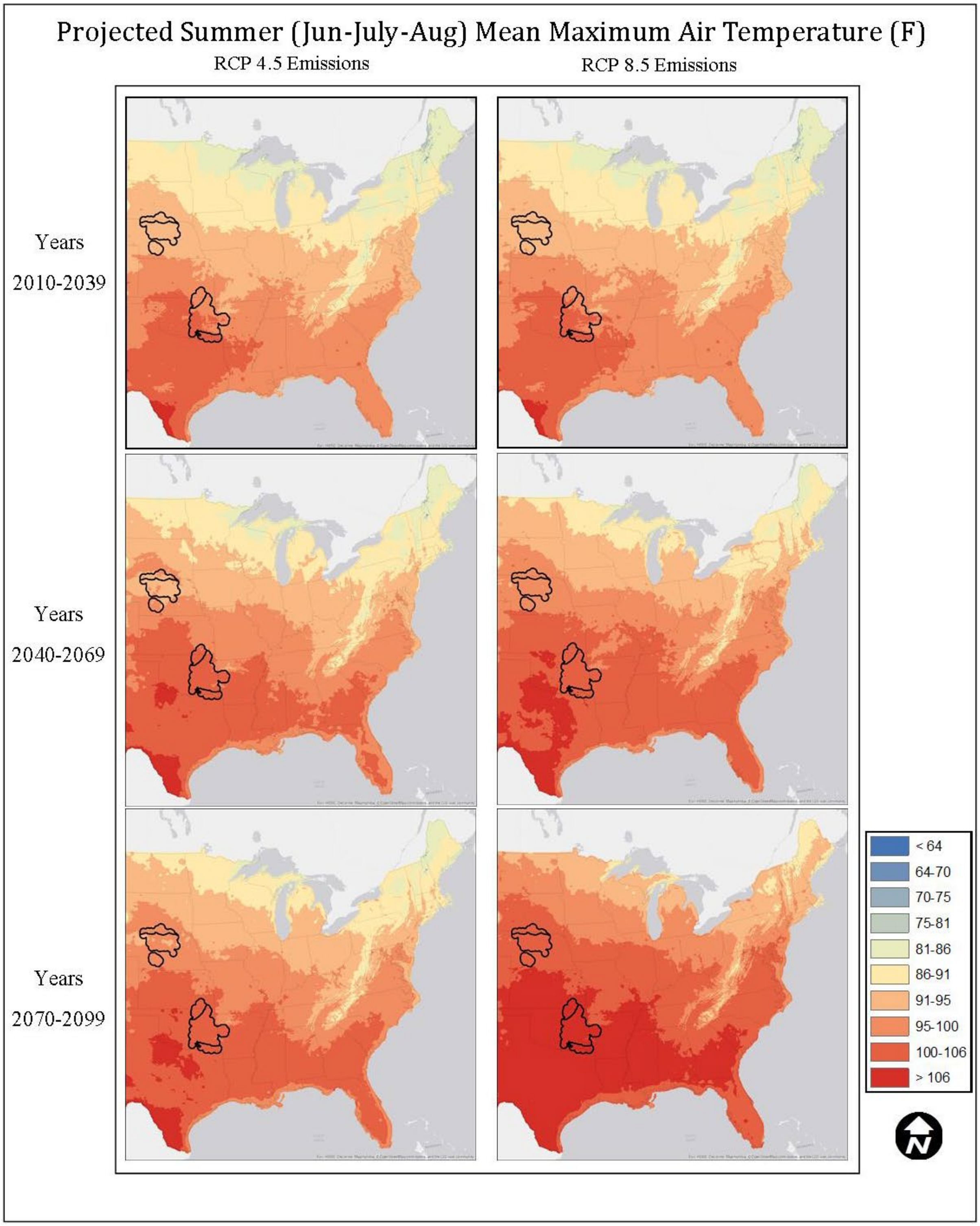


Figure 5-6. Projected summer maximum air temperature (F) for time periods 2010-2039, 2040-2069, and 2070-2099 under two climate change scenarios – RCP 4.5 and 8.5. The presented temperatures are the mean of 20 climate change models using the MACAv2-METDATA downscaling.

Southern Plains Analysis Areas

<u>*Red River Analysis Area*</u>

Southern portions of the Red River analysis area already have mean maximum temperatures of 94-95° F in July and August and recent survey information suggests the ABB may be extirpated in portions of this analysis area, including the portions of this analysis area in Texas and Arkansas. At both the moderate (RCP 4.5) and high (RCP 8.5) emission levels, climate change is projected to make future climate in the Red River analysis area near (99% of the Analysis Area in RCP 4.5) or at (100% of the Analysis Area in RCP 8.5) the presumed threshold (mean maximum air temperatures in June, July, and August of >95° F, see section 5.2.2.1 above) of the ABB by 2039 (Figures 5-7 and 5-8). Mean maximum temperatures (averaged over 2010 through 2039) during the June-August time period are predicted to be 95.8 for the moderate emissions and 96.1 for the high emissions level of change during the first third of this century. During the 2040 to 2069 period, mean maximum air temperatures are predicted to exceed the 95° F threshold temperature by at least 3-4 degrees F.

This trend of temperatures increasing beyond the assumed threshold is expected to follow in the other analysis areas. In the moderate emissions scenario, threshold temperatures (>95° F) will cover about half of the Southern Plains analysis areas within 30 years and all but a few small portions of the Southern Plains analysis areas within 60 years. All of the Southern Plains analysis areas would be within the nearing (94-95° F) or above (>95° F) temperature thresholds by 2069 and the entire area is expected to be above the threshold by 2099 (Figure 5-6). With moderate emissions, the Northern Plains analysis areas will likely remain below these threshold temperatures during the 90 year prediction interval (Figure 5-7).

The progression of threshold temperatures will be more aggressive under the high emissions scenario (Figure 5-8). A majority of the Southern Plains analysis areas will be near or exceed threshold temperatures by 2039, with potential to extirpate ABBs from most or all Southern Plains populations. By 2040-2069 the entire Southern Plains area will exceed threshold temperatures, likely resulting in extirpation of the ABB from this area. Threshold temperatures will begin encroaching on the northern analysis area by 2069 and exceed those thresholds by 2099. Under the high emissions scenario, climate changes are expected to completely extirpate the ABB from the Northern Plains analysis areas during the last 30 years of climate change projections (by 2099).

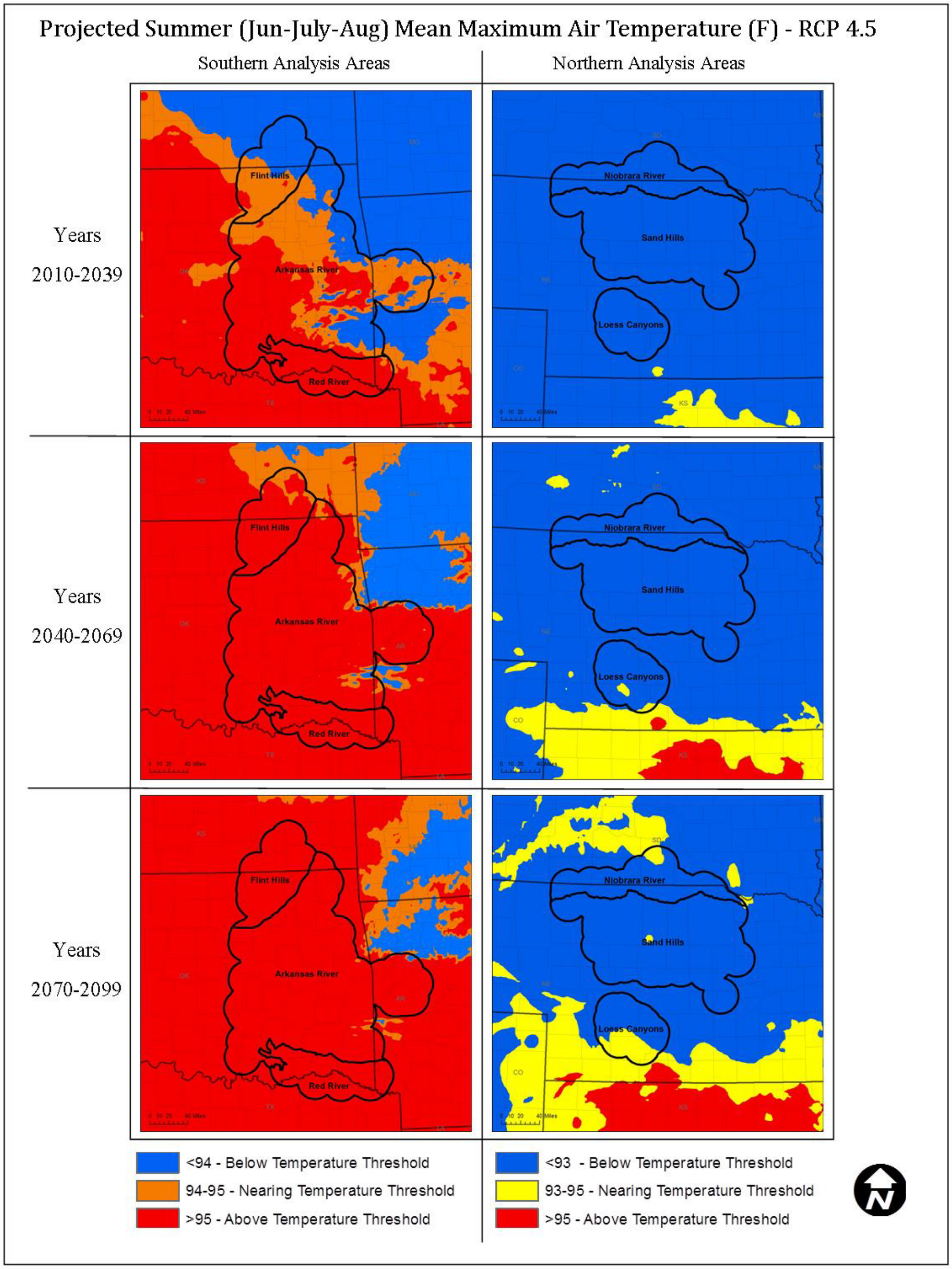


Figure 5-7. Projected summer temperature (Jun-July-Aug) of mean maximum air temperature (F) under the low emissions scenario – RCP 4.5. Colors indicate if temperatures have reached the ABB's survival threshold (red) or are nearing the threshold (orange for Southern and yellow for Northern Analysis Areas) where we anticipate effects to the species could take place. Blue indicates temperatures that have not reached the threshold and we do not anticipate temperature related effects. Data Source: MACAv2-METDATA, Multi-Model Mean.

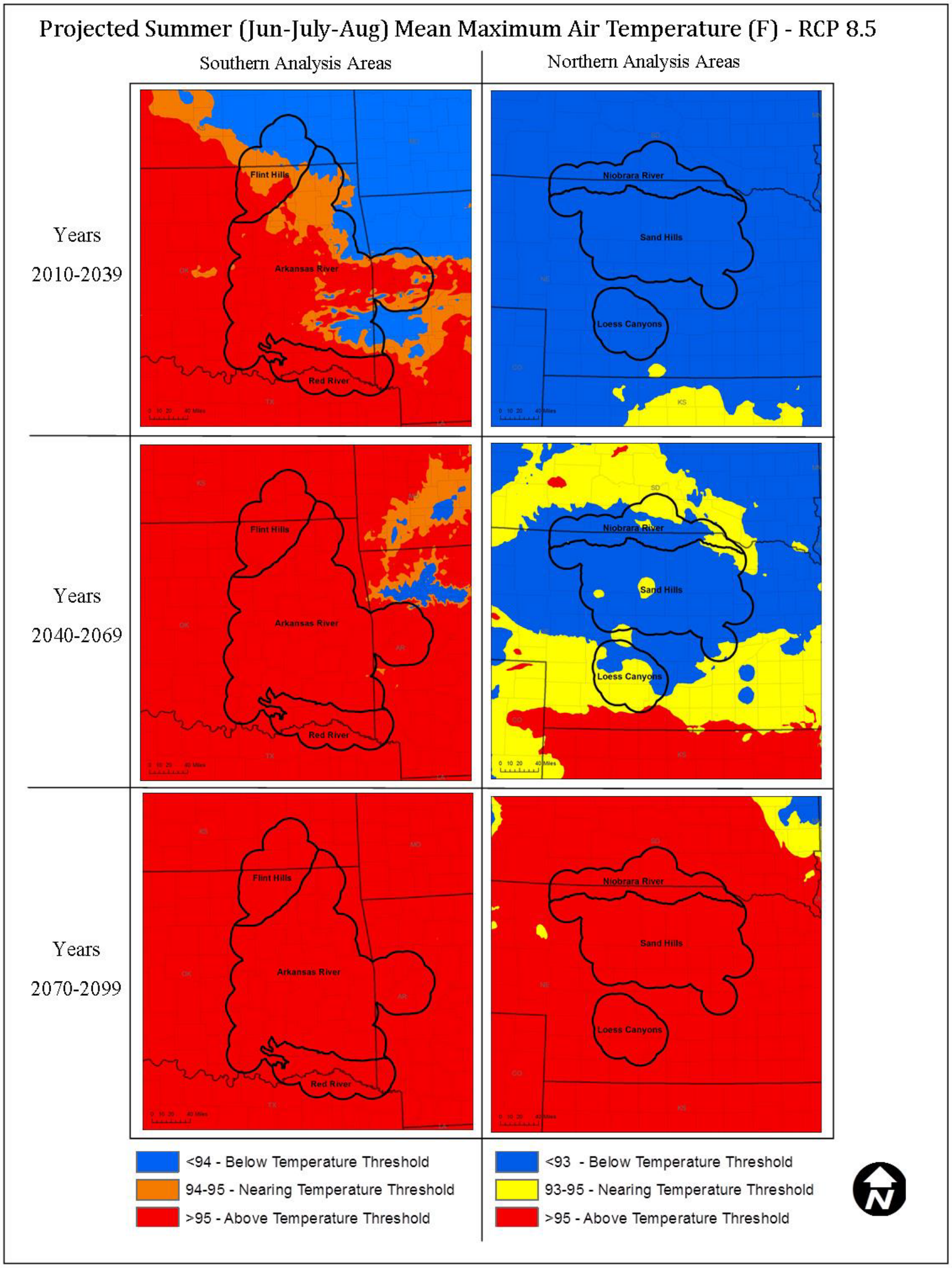


Figure 5-8. Projected summer temperature (Jun-July-Aug) of mean maximum air temperature (F) under the high emissions scenario – RCP 8.5. Colors indicate if temperatures have reached the ABB's survival threshold (red) or are nearing the threshold (orange for Southern and yellow for Northern Analysis Areas) where we anticipate effects to the species could take place. Blue indicates temperatures that have not reached the threshold and we do not anticipate temperature related effects. Data Source: MACAv2-METDATA, Multi-Model Mean.

The Red River Analysis Area is at the southern and western edge of the current occupied range in portions of Arkansas, Texas and Southeastern Oklahoma (Figure 5-1, above). The effects of climate change and increasing temperatures tends to make the effect of all other future risk factors irrelevant. Southern portions of the analysis area already have mean maximums of 94-95° F in July and August and recent survey information suggests the ABB may be extirpated in Texas. At both the moderate and high emission levels, climate change is projected to make future climate in this analysis area at or near the presumed threshold (mean maximum air temperatures of 95° F) of the ABB by 2039 (Figures 5-7 and 5-8).

Only slight changes in annual precipitation are predicted for this analysis area, but precipitation events are expected to be larger with longer periods of no precipitation between events Shafer et al. 2014 (pages 441-445). Soil surface moisture levels have declined in this area between 1988 and 2010 (Georgakakos, A., P. et al. 2014, page 72) and this area may be sensitive to even minor changes in soil moisture because it was already at the southern and western edge of the species range (Figure 5-9).

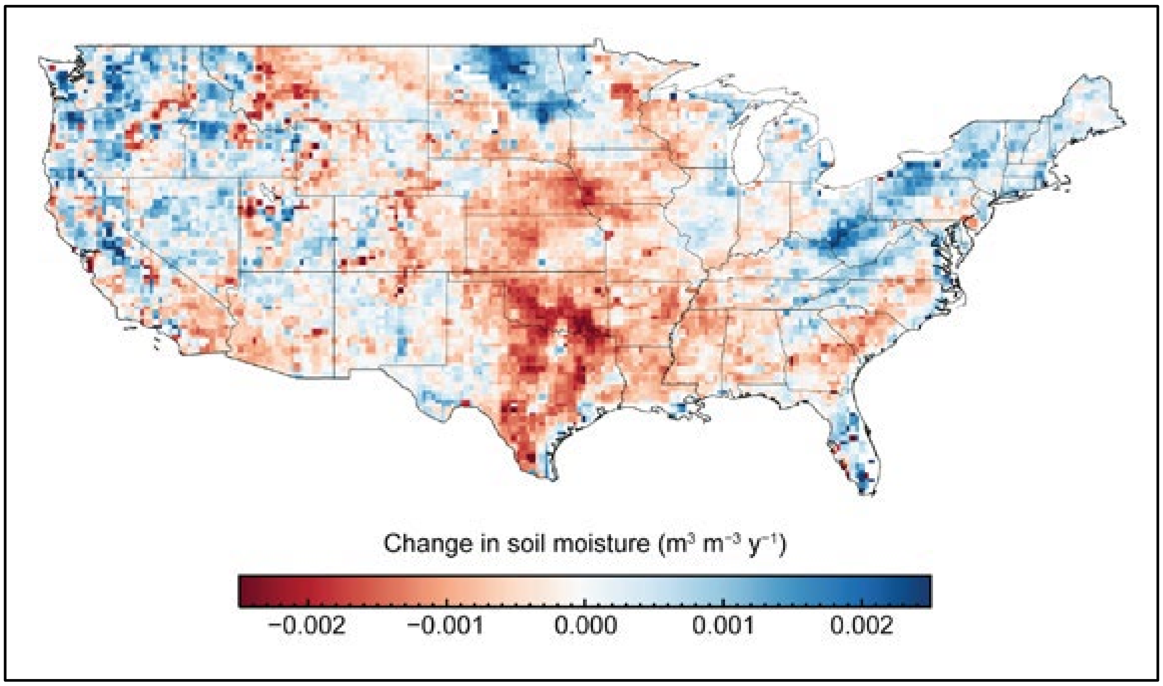


Figure 5-9. Changes in annual surface soil moisture per year over the period 1988 to 2010 based on multi-satellite datasets. Surface soil moisture exhibits wetting trends in the Northeast, Florida, upper Midwest, and Northwest, and drying trends almost everywhere else. (Images provided by W. Dorigo).

<u>Summary of Climate Change Effects on the Red River Analysis Area</u> - The effects of climate change and increasing temperatures makes all other future effects irrelevant (Table 5-18). The effects of climate change, at both the moderate and high emission level, are predicted to make all

habitats in this analysis area unsuitable by 2039 and those effects may already be occurring. Mean maximum temperatures during the July-August time period are already at or near 94-95° F in portions of this analysis area. The current resiliency of the Red River Analysis Area is considered low and future resiliency is zero due to the limited distribution, very low and declining ratios of positive to negative surveys in recent years, and potential climate change effects.

Table 5-18. Future resiliency with land use changes and two (RCP 4.5 and 8.5) climate emission scenarios.

	Future Resiliency - Including Future Climate						
Analysis Area	**Future Resiliency with Land Use** (from Table 5-4)	**Climate Change (2010 - 2039)**		**Climate Change 2040 - 2069)**		**Climate Change (2070 – 2099)**	
		Moderate Emissions RCP 4.5	**High Emissions RCP 8.5**	**Moderate Emissions RCP 4.5**	**High Emissions RCP 8.5**	**Moderate Emissions RCP 4.5**	**High Emissions RCP 8.5**
Northern Plains							
Niobrara River	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**Moderate-Low**	**Moderate-Low**	**Ø**
Sand Hills	**High**	**High**	**High**	**High**	**High**	**High**	**Ø**
Loess Canyons	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Ø**
Southern Plains							
Flint Hills	**Moderate**	**Low**	**Low**	**Ø**	**Ø**	**Ø**	**Ø**
Arkansas River	**High**	**Low**	**Low**	**Ø**	**Ø**	**Ø**	**Ø**
Red River	**Low**	**Ø**	**Ø**	**Ø**	**Ø**	**Ø**	**Ø**
New England							
Block& Nantucket	**Moderate-Low**	**Moderate-Low**	**Moderate-Low**	**Moderate-Low**	**Moderate-Low**	**Moderate-Low**	**Moderate-Low**

Arkansas River Analysis Area

The more direct effects of climate change and increasing temperatures tends to make all other future effects irrelevant. At both the moderate and high emission levels, climate change is predicted to make all habitats in this analysis area at or near the presumed threshold (mean maximum air temperatures of 95° F) for being unsuitable by 2039. Mean maximum temperatures during the June-August time period are predicted to be 94.67° F for the moderate emissions and 95.08° F for the high emissions level of change for the 2010- 2039 time period (30 year mean, Figure 5-7 and 5-8). This will result in 43% (RCP 4.5) or 64% (RCP 8.5) of the analysis area above the threshold, with an additional 51% (RCP 4.5) or 34% (RCP 8.5) within 2 Fahrenheit degrees of the threshold. By 2069 mean maximum air temperatures are predicted to exceed the threshold temperatures by at least 3-4 degrees (96% and 100% of land area above the threshold for RCP 4.5 and 8.5 respectively). Only slight changes in annual precipitation are predicted for this analysis area, but precipitation events are expected to be larger with longer periods of no precipitation between events. Extended droughts are expected to reduce populations more often in the future and rising temperatures will likely limit reproduction and potential for recoveries from stochastic events. With climate change, a major decline in abundance and distribution in most or all of this analysis area is expected by 2039. Small portions (about 10%) of this analysis area are below the 94° F near threshold in 2039 under both the moderate and high emissions levels (Figure 5-7 and 5-8), but these areas are primarily higher elevation areas in old mountain ranges that have poor rocky soils and have few positive ABB surveys. About one half of the analysis area is above the 95° F threshold in the moderate and about two thirds of the area is above the 95° F threshold at the high emissions level by 2039. Nearly all of the analysis area exceeds the 95° F threshold by 2069 at both emissions levels. Resiliency within the Arkansas River Analysis Area with the forecasted climate changes is expected to be low by 2039 and zero by 2069 and 2099 under both the moderate and high emissions levels (Figure 5-7 and 5-8).

Summary of Climate Change Effects on the Arkansas River Analysis Area - With climate change, future resiliency is considered low to zero by 2039 and zero for any longer time frame. Habitat conditions, population abundance and distribution are all likely to be affected by climate changes. A major decline in abundance and potential extirpation for most or all of this analysis area is expected by 2039. No portions of this analysis area are expected to support ABBs by the end of the next 30 year period in 2040-2069 based on current climate projections

Flint Hills Analysis Area

Habitat conditions, population abundance and distribution are all likely to be affected by climate changes. Extended droughts are expected to reduce populations more often in the future and rising temperatures will likely limit reproduction and potential for recoveries from stochastic events. With climate change, a major decline in abundance in most or all of this analysis area is expected by 2039. Only a small portion is actually predicted to be above the 95° F threshold (4% for RCP 4.5 and 32% for RCP 8.5), but most of the remaining area for this analysis area (73% for RCP 4.5 and 64% for RCP 8.5) is at the 94° F near threshold in 2039 under the two emissions scenarios (Figure 5-7 and 5-8). Future resiliency is considered low by 2039 and zero for any longer time frame.

Summary of Climate Change Effects on the Flint Hills Analysis Area - A decline in ABB abundance and distribution for most of this analysis area is expected by 2039. With climate change, future resiliency is considered low by 2039 and zero for any longer time frame. No portions of this analysis area are expected to support ABBs by the end of the next 30 year period in 2040-2069, based on current climate projections.

Summary of Climate Change Effects on the Southern Plains Analysis Areas

The Red River Analysis Area may already be affected by current or recent climate conditions (see section 4.2.2). Habitat conditions, population abundance and distribution in nearly all portions of the Southern Plains Analysis Areas are likely to be affected by climate changes by 2039 with only small portions of the Arkansas River and Flint Hills Analysis Areas that are not near or above the 95° F threshold at the moderate and high emissions level (see Figure 5-5 and 5-6). Nearly all of the Southern Plains analysis areas are predicted to be above the 95° F threshold by 2040-2069 and no portions are expected to support ABBs by 2069 or 2099, based on current climate projections (see Figures 5-7 and 5-8). Even the most optimistic scenario with RCP 2.6 projects summer temperatures above the 95° F threshold by 2040-2069. Future resiliency is considered zero for the Red River, low for the Arkansas River and Flint Hills analysis areas by 2039, and zero for all southern analysis areas for any longer time frame. The genetic diversity of ABB populations may help them adapt to some future conditions, but the rate of climate related changes is too rapid. It is not realistic to expect ABBs to adapt to the projected temperature increases within a 20 year timeframe and projected summer mean maximum temperatures by 2070-2099 would approach 100° F under RCP 4.5 and 105 ° F under the RCP 8.5 in the Southern Plains Analysis Areas scenario. These temperatures would likely extirpate all Nicrophorus species in the Southern Plains.

Northern Plains Analysis Areas

Loess Canyons, Sandhills, and Niobrara River

The effects of climate changes are similar for all three analysis areas in the Northern Plains and discussions for the effects of climate changes on the Loess Canyons, Sandhills, and Niobrara River analysis areas are combined in this section. By 2039, none of the Northern Plains analysis areas are expected to approach the 93-95° F near threshold (Figure 5-7 and 5-8). Mean maximum temperatures for June-August increase to near 90° F and precipitation is expected to be slightly less than current levels during June-August, but slightly higher on an annual basis (Source MAVAv2-METDATA, see section 5.3.1). With moderate or high emissions, future resiliency is considered low for the Loess Canyons, moderate for the Niobrara River analysis areas and high for the Sandhills Analysis Area by 2039 (Table 5-18).

By 2040-2069, only small portions (6%) of the Loess Canyons Analysis Area are expected to reach the 93-95° F near threshold under the moderate emissions level, but most of this analysis area (67%) and small portions of the Sandhills (7%) and Niobrara River (25%) analysis areas meet that threshold under the high emissions level (see Figure 5-7 and 5-8). Mean maximum temperatures for all three analysis areas increase to above 90° F and precipitation is expected to be slightly less during June-August, but slightly higher on an annual basis (increase by about1/2 inch or less, Source MAVAv2-METDATA, see section 5.3.1). For example, the precipitation in the Sandhills Analysis Area during the June-Aug timeframe is predicted to decline from the historical average of 9.47 inches by less than 1 inch to 8.81 inches with moderate emissions and 8.68 inches with high emissions in 2040-2069. Annual precipitation is not expected to change much (increase by about1/2 inch or less) under any of the climate change scenarios (Source MACAv2-METDATA, see 5.3.1). With moderate emissions, future resiliency is considered low for the Loess Canyons, moderate for the Niobrara River analysis areas and high for the Sandhills Analysis Area by 2069 (Table 5-18). Under high emissions, temperatures approach the 93-95° F near threshold levels in about 2/3 of the Loess Canyons Analysis Area, about 20% of the Niobrara Analysis Area and small portions of the Sandhills Analysis Area (see Figure 5-8) in the 2040-2069 timeframe. The resiliency for the Niobrara River Analysis Area could change to low because the 93-95° F areas are at or near the areas of ABB concentrations in this timeframe.

By 2070-2099, the effects of climate change have more potential to affect the ABB populations in the Northern Plains. The effects at the moderate emission levels, are not predicted to exceed the presumed 95° F threshold out to 2099 (0% of all northern analysis areas, see Figure 5-7 and 5-8). However, portions of the analysis areas (35% of the Loess Canyons and 5% of the Niobrara Analysis Areas) are in the near threshold range of 93-95° F and the ABBs in northern analysis areas may not have the same temperature tolerances or thresholds as the ABBs in southern analysis areas. With moderate emissions, future resiliency is considered low for the Loess Canyons, moderate to low for the Niobrara River analysis areas and high for the Sandhills Analysis Area by 2070-2099 (Table 5-18).

The effects of climate change at the high emissions level (RCP 8.5) are much greater and temperature increases are predicted to make mean maximum temperatures in all three northern analysis areas exceed the 95° F threshold by about 2-3 degrees. With high emissions, 100% of all Northern Plains analysis areas will exceed the threshold within the 2070-2099 timeframe. Mean maximum temperatures during the June-August time period are predicted to be 97.95 ° F for the Loess Canyons, 96.73° F for the Sandhills and 97.09° F for the Niobrara River analysis areas with the high emissions level of change by the 2070-2099 timeframe (Figure 5-8). Only relatively small changes in annual precipitation are predicted for this analysis area, but precipitation events are expected to be larger with longer periods of no precipitation between events. Precipitation during the June-Aug timeframe in the Sandhills Analysis Area is predicted to decline from the historical average of 9.47 inches to 8.14 inches for the high emissions scenario (Source MAVAv2-METDATA, see section 5.3.1). Annual precipitation for any of the analysis areas is not expected to change much (increase by about 1 inch or less) under any of the climate change scenarios (Source MAVAv2-METDATA, see section 5.3.1). Future resiliency is considered zero for all Southern and Northern Plains analysis areas by 2070-2099.

Summary of Climate Change Effects on the Northern Plains Analysis Areas

Habitat conditions, population abundance and distribution are all likely to be affected by climate changes. Potential extirpation is likely for all of the Northern Plains analysis areas by 2070-2099 under the high emissions level. Under the moderate emissions level, populations in all Northern Plains analysis areas should be maintained through 2099, but some reductions in abundance and distribution are possible as temperatures approach the temperature threshold levels. Future resiliency is potentially the same as current resiliency for all Northern Plains analysis areas (except the Loess Canyons Analysis Area) through 2039-2069, but climate changes reduce or eliminate the resiliency (depending on emissions levels) by 2070-2099 (see Table 5-18).

New England Analysis Areas

The New England Analysis Area consists of two islands where ABB are known to occur: Block Island, RI and Nantucket, MA. The current resiliency of the analysis area is considered moderate due to the limited area of potential habitat, relatively good distribution, and moderate ratios of positive to negative surveys (compared to other analysis areas, see Table 4-3).

Block Island is considered to have relatively high resiliency with active management. Nantucket is a reintroduced population with lower resiliency with lower ratios of positive to negative surveys. Climate change is not expected to increase temperatures near any possible thresholds by 2099. Mean Maximum temperatures for June-August are only expected to rise to about 77° F by 2099. Climate related increases in sea levels are not expected to inundate any ABB suitable habitat, but some habitat could be affected during storms due to the increased tides and storm surges. At the high emissions level of climate change this may be the only remaining population of ABBs. Land use changes and effects to ABBs are predicted to be relatively minor through 2099 because most of the existing suitable habitat is protected (54%) and climate changes are expected to have only minor negative effects on the existing New England populations. The current resiliency (moderate) would be maintained under scenario 1 because active management has helped maintain these island populations.

5.4.2.2 Nights with Temperatures above 75°F

Regardless of whether nights above 75°F were observed in the historical period, the number of those nights per year increased in all analysis areas during the prediction period (2010-2099). For the lower emission scenario (RCP 4.5) nights above 75°F began to increase in the Northern Plains analysis areas after 2025 (Figure 5-10 and Appendix C). As these nights were already increasing in the historical record for the southern analysis areas, they continued to increase until around 2075 when there appears to be an asymptotic limit to nights above 75°F between 40 and 60 nights per year (Figure 5-10 and Appendix C). Nights above 75°F increased more dramatically under the higher emission scenario (RCP 8.5). Increases in the Southern Plains analysis areas resemble straight lines, with none of the asymptote apparent in the lower emissions scenario (Appendix C). Again, because nights above 75°F were not observed during the historical period for the Northern Plains analysis areas, those areas are slower to increase at first, but quickly increase beginning around 2030 to 2050 for all Northern Plains analysis areas.

Historical records for nights above 75°F maxed out at between 4 and 18 nights per year (Chapter 4). With the exception of Freedonia, KS, all other locations within the Southern Plains analysis areas exceeded 18 nights above 75°F per year during the first 30 years of predictions (2010 to 2039, Table 5-11). Climate predictions for the end of the 21st century indicate that nights above

75°F will triple to quintuple resulting in up to 97 nights per year above 75°F in Hugo, OK (RCP 8.5, Table A). Results for 2099 in the Northern Plains analysis areas are not as dire as the Southern Plains areas with nights above 75°F equaling or slightly exceeding historical records for the southern analysis areas. Surprisingly, the northernmost sampling point (Colome, SD – Appendix C) is predicted to exceed most or all of the Northern Plains analysis areas in nights above 75°F (Table 5-11).

Though mean predictions of nights above 75°F for some areas rarely or never exceeded one standard deviation above zero (Appendix C), all locations and emissions scenarios exhibited significant positive relationships with time. Though all relationships explained greater than 57% of the variability in predicted days above 75°F, most relationships explained more 80% of variability. These relationships indicate that despite difficulties differentiating any individual point or location from no change, the overall trend at each location is highly significant and increases with time.

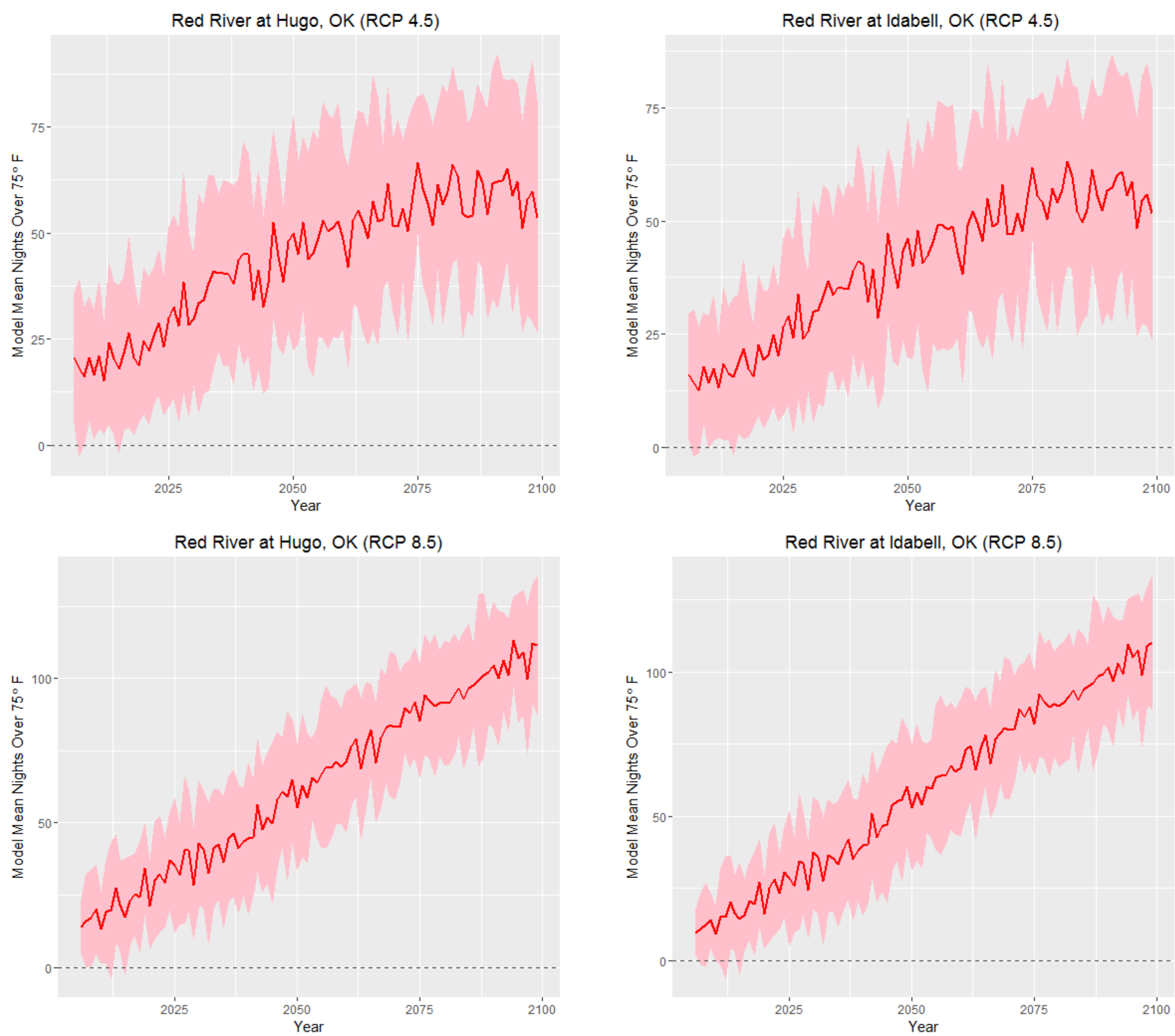


Figure 5-10. The mean (red line) and standard deviation (pink shading) of 20 statistically downscaled climate change models for two locations (East = Idabell, OK; West = Hugo, OK) within the Red River Analysis Area. Each graph shows the change over time in the mean number of nights with minimum temperatures greater than or equal to 75°F. American Burying Beetles in captivity cannot reproduce when temperatures exceed 75°F. Figures for other analysis area are provided in Appendix C.

Table 5-11. Mean number nights above 75°F for each of the analysis areas during thirty year periods. RCP are Relative Concentration Pathways representing possible emission scenarios.

Analysis Area		Mean Number of Nights Above 75°F		
Nearest Town	RCP	2010 - 2039	2040 - 2069	2070 - 2099
Red River				
Idabell, OK	4.5	24.9	44.3	54.8
	8.5	26.9	61.3	94.6
Hugo, OK	4.5	28.8	47.9	58.3
	8.5	32.1	65.4	97.3
Arkansas River				
Van Buren, AR	4.5	22.1	38.8	48.5
	8.5	25.2	55.5	88.3
Shawnee, OK	4.5	30.1	46.9	56.0
	8.5	33.5	62.3	91.2
Flint Hills				
Freedonia, KS	4.5	14.5	27.4	34.6
	8.5	17.2	39.9	67.6
Webb City, OK	4.5	26.4	41.3	49.0
	8.5	29.5	54.7	82.1
Loess Canyons				
Lexington, NE	4.5	0.7	3.3	4.9
	8.5	1.0	7.3	24.8
Wellfleet, NE	4.5	0.2	1.4	2.3
	8.5	0.5	3.9	17.6
Sand Hills				
Amelia, NE	4.5	0.5	2.5	4.3
	8.5	0.8	6.1	21.7
Thedford, NE	4.5	0.1	0.6	1.2
	8.5	0.2	2.2	12.4
Niobrara				
Colome, SD	4.5	1.3	4.0	6.5
	8.5	1.7	8.4	24.7
Merriman, NE	4.5	0.1	0.5	0.9
	8.5	0.16	1.79	10.58

5.4.3 Representation

The combination of land use changes and projected climate changes could reduce representation, or diversity of the species. The Southern Plains analysis areas are at high risk of extirpation due to climate changes under both the moderate and high emissions options by 2039-2069 and temperatures would be at least 2-4 degrees above the current assumed threshold (June-August Mean Maximum of 95 ° F) by 2069. The ABBs in the southern analysis areas are not known to have unique genetic diversity, but could have behavioral differences that represent regional adaptations to warmer climates. It is possible the populations have different life history strategies, due to variations in ecological drivers that have not yet been identified. ABBs in the Northern Plains analysis areas are also at risk of extirpation due to climate change, but on a longer time frame. Temperatures are not predicted to reach potential threshold levels until the 2070-2099 timeframe and only at the high emissions level of climate change. The New England Analysis Area is not threatened by climate change related increases in temperatures because the islands temperatures are moderated by the Atlantic Ocean. Mean Maximum temperatures for June-August are not predicted to exceed the upper 70s° F by 2099 in the New England Analysis Area. At the high emissions level of climate change, the New England population is likely to be the only remaining genetic diversity unless new populations from other analysis areas are established in more northern areas, or populations are maintained in captive conditions. Under scenario 2 the representation provided by the New England populations is questionable because resiliency is considered low without active management.

5.4.4 Redundancy

Redundancy with the high emissions level climate change would go from current conditions to only one or two New England island populations by 2099. Under scenario 1 with active management, New England would maintain two island populations. Under scenario 2 with no active management, the Nantucket population would be extirpated and the Block Island population may maintain itself. However, the Block Island resiliency is considered low without active management. The ABB populations in all other analysis areas would be extirpated. At the moderate emissions level of climate change (out to 2099) redundancy would decline from eight to five (or four) populations with ABBS surviving in the Northern Plains (Niobrara, Sandhills, and possibly Loess Canyons), and one or two (2 populations under scenario 1 and 1 population under scenario 2) within the New England Analysis Area (Block Island and Nantucket). If successful, the Ohio reintroduction could add to the redundancy, but the Missouri reintroduction is expected to be extirpated by 2069 with climate changes (moderate and high) similar to northern portions of the Southern Plains analysis areas.

5.4.5 Summary of Viability with Future Climate Conditions

High emissions levels of climate change would result in the representation and redundancy associated with only one or two small island populations with limited genetic and ecological diversity by 2070-2099. The only representation remaining would be the in the New England Analysis Area. Under scenario 1 with active management, New England would maintain two island populations. Under scenario 2 with no active management, the Nantucket population would be extirpated and the Block Island population may maintain itself. However, the loss of all ABB populations is possible because the Block Island resiliency is considered low without active management. ABBs in the Southern Plains and Northern Plains analysis areas are all predicted to be extirpated under the high emissions level of climate change by 2070-2099. The high emissions (RCP 8.5) level closely represents the current rates of climate change and a very realistic scenario.

At the moderate emissions level of climate change (out to 2099), northern analysis areas may continue to support ABBs, but the species viability would be reduced due to a loss of representation and redundancy with the extirpation of southern analysis areas and the introduced population in Missouri (assumed to occur by 202040-2069). The Loess Canyons Analysis Area has low resiliency by 2039 and could be extirpated as well due to a combination of eastern red cedar expansion and sensitivity to droughts. With moderate emissions levels of climate change the viability would potentially be represented by northern analysis areas in Nebraska, South Dakota, New England, and possibly successful reintroductions in Ohio. However, the Sandhills would be the only high resiliency population remaining and the Niobrara River may be the only moderate resiliency population by 2070-2099. New England may have moderate resiliency with active management. All other remaining populations would have low resiliency unless new reintroductions are successful.

5.5 STATUS ASSESSMENT SUMMARY

The species status assessment for ABBs uses the analysis of current conditions and potential future scenarios to assess future resiliency for analysis areas and viability of the species over their current range.

5.5.1 Current Viability

Chapter 4 addresses the current status of ABBs in the 8 analysis areas. The current resiliency is at least moderate for all analysis areas except the Red River Analysis Area and high for at least 2 analysis areas. Current overall representation is considered moderate. The current genetic diversity appears to be relatively high, but the ecological diversity has been reduced with the loss of about 90 percent of the historical range. The current known range does include populations from northern and southern areas and eastern and western areas of the ABB range, although representation from eastern areas is limited to the New England island populations. Current redundancy is limited to 8-9 ‘populations’, 3 in the Southern Plains (Arkansas River, Red River, and Flint Hills), 3 in the Northern Plains (Niobrara, Sandhills, and Loess Canyons), two within the New England Analysis Area (Block Island and Nantucket) and the Missouri reintroduction if we assume continued active management. Reintroduction efforts may add to the future redundancy, and the Missouri reintroduction appears to be successful, but it is too early to tell if these reintroductions will be successful or self-sustaining over any length of time.

Although analysis areas within the southern and northern areas are not known to have unique genetic representation, the presence of both northern and southern populations does improve representation by maintaining the genetic diversity and ecological diversity (also called environmental variation or diversity) of the species. The more representation, or diversity, the species has, the higher it’s potential of adapting to changes (natural or human caused) in its environment. We consider populations within these northern and southern areas to provide some form of representation and redundancy due to differences in habitat diversity, existing threats, land use patterns, and climate, as described above. The redundancy provided by the Red River Analysis Area currently appears to be very limited or could be discounted with only seven positive surveys in the last five years. However, the large area of potentially occupied habitat in the Flint Hills and Arkansas River analysis areas (total of 17,316,682 potentially suitable acres) helps support the existing redundancy, representation and resiliency for the Southern Plains. If one or more populations exist in southeastern areas of the ABB historic range, it would provide additional redundancy.

5.5.2 Future Viability

The primary risk factors that have potential to change the status of ABBs in the future are habitat availability and suitability, as driven by changes in land uses and climate. Most of the other risk factors are determined or strongly influenced by land use and climate.

5.5.2.1 Scenario 1 – Continued Current Rate of Land Change and High Protection/Management

This represents our assumptions for status quo continuation into the future. There are no changes anticipated in condition categories for future habitat, population factors or resiliency under scenario 1 for land use changes alone (Table 5-9). Agricultural land uses and urban expansion are predicted to have some impacts to ABB habitat over time, but the impacts affect a relatively small percentage of the analysis areas. There are some urban areas in the Southern Plains analysis areas, but they are not near any areas of ABB concentrations or the concentrations near urban areas are on protected lands that would not be affected by urban expansion. The land use changes under scenario 1, (with high protection/management or best case) would result in only minor reductions relative to the current viability and population resiliencies. Future ABB representation and redundancy should not be affected by scenario 1.

5.5.2.2 Scenario 2 Accelerated Rate of Land Change and Low Management

The changes in land use do increase losses of suitable habitat, but most analysis areas are large and the potential losses affect resiliency of two analysis areas (using current criteria). The scenarios lack of management for ABBs has relatively little impact because few areas currently have active management for ABBs. The exceptions to this would be the Loess Canyons, New England populations and all reintroduction sites that are currently managed for ABBs. The Loess Canyons Analysis Area has low resiliency by 2039 due to a combination of eastern red cedar expansion (limited fire or mechanical control) and sensitivity to droughts. Future resiliency for New England would be fair with land use changes alone, but is considered poor without continued carcass provisioning. The current resiliency (moderate) is largely due to the active management (especially on Nantucket Island) and reducing or eliminating the active management is likely to reduce the abundance of ABBs on Block Island and cause the extirpation of ABBs on Nantucket Island. Condition categories for future population factors and resiliency are reduced under scenario 2 (Table 5-17). The lack of active management is expected to result in low resiliency for New England under scenario 2.

5.5.2.3 Inclusion of Future Climate Conditions

Scenarios 1 and 2 were analyzed with land use projections first so we could assess the effects of potential future land use alone. The effects of climate changes (both RCP 4.5 and 8.5) were then incorporated into both land use scenarios (1 and 2) to represent the combined effects of land use and climate change on ABB populations. The effects of potential climate changes outweigh all land use changes except in the New England analysis area. Land use changes are relatively minor in most analysis areas and are no longer relevant when climate changes make these habitats unsuitable. Once temperatures and moisture thresholds are exceeded, even the best habitats (with land uses designed to benefit the ABBs) are no longer able to support populations. There are no major differences between scenarios with climate change, and climate change combined with land use changes except in the Loess Canyons and New England analysis areas.

By 2039, the levels of land use change (scenarios 1and 2), with moderate and high climate change, would result in reduced resiliency in all southern analysis areas and reductions in redundancy. The Red River Analysis Area would be extirpated and the Arkansas River and Flint Hills analysis areas would have low resiliencies. Northern analysis areas would have minor adverse effects related to climate changes and habitat loses due to land use changes would reduce the resiliency of the Loess Canyons Analysis Area to low.

By 2040-2069, ABBs in all southern analysis areas would likely be extirpated and this is a loss of about 59% of the current range. The summer mean maximum threshold (95° F) would be exceeded in nearly all portions of the southern analysis areas under either the moderate or high emissions levels of climate change. Northern analysis areas are largely unaffected by moderate emissions levels of climate change by 2069. However, at high emissions, temperatures approach the 93-95° F near threshold levels in about 2/3 of the Loess Canyons Analysis Area and small portions of the other two analysis areas in the Northern Plains (see Figure 5-5). The combination of land use and climate changes is predicted to have some effects on the resiliency of northern analysis areas. Future resiliency is considered low for the Loess Canyons, low-moderate for the Niobrara River and high for the Sandhills analysis areas (see Table 5-18?). Representation and redundancy would be reduced.

By 2070-2099, the effects of climate change have more potential to affect the ABB populations in the Northern Plains. The effects at the moderate emission levels are not predicted to exceed the presumed 95° F threshold out to 2099 (see Figure 5-6, 5-7). However, portions of the analysis areas (about 2/3 of the Loess Canyons Analysis Area) are in the near threshold range of 93-95° F and the ABBs in northern analysis areas may not have the same temperature tolerances or thresholds as the ABBs in southern analysis areas. The thresholds for climate related effects on northern ABB populations have not been researched, and assumptions that their tolerances are similar to southern populations should be considered with caution until additional research can be conducted. With moderate emissions and scenario 1or 2 land use changes, future resiliency is considered low for the Loess Canyons, low-moderate for the Niobrara River and high for the Sandhills Analysis Area by 2099 (see Table 5-18). Populations in the Northern Plains and New England would provide the ABB's remaining resiliency, redundancy, and representation by 2070-2099 with moderate emissions. Redundancy would be provided by 3 remaining populations from the Northern Plains and 1-2 populations from New England (depending on the long-term success of the reintroduced Nantucket Island population and the level of active management). With moderate emissions, representation would be limited to the genetic and ecological diversity represented by Northern Plains and New England populations. The diversity of the southern analysis areas would be lost unless efforts to preserve that diversity through new reintroductions or captive populations are successful.

The effects of climate change at the high emissions level are much greater and mean maximum temperatures in all three Northern Plains analysis areas by 2070-2099, are expected to exceed the 95° F threshold by about 2-3 degrees. Mean maximum temperatures during the June-August time period are predicted to be 97.95 ° F for the Loess Canyons, 96.73 ° F for the Sandhills and 97.09° F for the Niobrara River analysis areas with the high emissions level of change by 2070-2099 (see fig 5-7). Only relatively small changes in annual precipitation are predicted for this analysis area, but precipitation events are expected to be larger with longer periods of no precipitation between events. Precipitation during the June-Aug timeframe in the Sandhills Analysis Area is predicted to decline from the historical average of 9.47 inches to 8.14 inches for the high emissions scenario (Source MACAv2-METDATA, see section 5.3.1). Annual precipitation for any of the analysis areas is not expected to change much (increase by about 1 inch or less) under any of the climate change scenarios (Source MACAv2-METDATA, see section 5.3.1).

At the high emissions level, future resiliency is considered zero for all western analysis areas by 2070-2099 and the New England analysis area would be the only remaining populations unless other reintroduced populations are established in northern areas. Climate changes are only anticipated to have minor effects (increased tides and storm surges) on New England populations. New England mean maximum temperatures for June-August are only expected to rise to about 77° F by 2099 and increases in sea levels are not expected to inundate any ABB suitable habitat. However, the resiliency of New England populations could be affected by impacts to existing habitat and is dependent on active management. The resiliency of the New England Analysis Area is considered low under scenario 2 without active management.

5.5.3 Other Factors Affecting Future Viability

5.5.3.1 Ability of the species to move north to adapt to climate change

If there were ABB populations at the northern edge of the species range that were limited by low temperatures (ABBs are not very active at night time temperatures below 55° F), it would be logical that a mobile species would expand to the north, assuming suitable habitat was available, as temperatures increased. However, there are no existing ABB populations that are near the historic northern range limits and no evidence that any existing populations are limited by low temperatures (see Figure 4.2). If suitable habitat was available to the north of existing populations, ABBs should already be present in those areas.

This would apply to existing areas in Kansas and Missouri that are between the Flint Hills or Arkansas River analysis areas and the Loess Canyons analysis area. If more suitable habitat was present in Kansas, ABBs from Oklahoma and southern Kansas could progressively move north as climate changed, but under the moderate or high emissions level of climate change, nearly all of Kansas is above the 95° F threshold temperature by 2069-2099 (see figures 5-7 and 5-8). Intensive agriculture, mostly in the form of row crops dominates the land to the north of existing populations in Nebraska and South Dakota and limits the suitability of that habitat to support ABBs. The ability of ABBs to move north as climate changes appears to be limited by a lack of suitable habitat to the north of any existing ABB populations in northern areas. Natural movement and adaptation to climate change for ABBs would require a corridor of suitable habitat to the north of existing populations.

There may be potential to reintroduce ABBs to habitat in northern areas that would maintain suitable temperatures with future climate changes. However, methods for reintroducing ABBs are still being developed and there are no reintroductions that have documented long-term success in restoring or establishing a viable population that is self-sustaining. Reintroductions on Nantucket Island and in Missouri have documented establishment of ABBs that have survived winters, but it is not yet known if these areas could maintain populations without supplementing carrion, monitoring and management.

5.5.3.2 Climate Effects to Carrion

Some potential carrion species may be affected by climate changes. Some species like pheasants in northern analysis areas may decline with increasing temperatures. Pheasants do not occur or are in very low numbers in the southern analysis areas and gradually increase in abundance as you move north to Kansas, Nebraska and South Dakota. If future temperatures in the Northern Plains become similar to what occurs in southern Oklahoma today, pheasants and possibly other suitable carrion species may no longer be abundant there. Other species like cotton rats have expanded to the north, but the shorter grass habitat that is native for the northern ABB habitat may not be as favorable to cotton rats, as they prefer dense vegetation.

5.5.3.3 Alternative Scenarios with Reintroductions in Northern Areas

An aggressive reintroduction alternative in northern portions of the historic range would be an option for maintaining or enhancing ABB redundancy and representation into the future. Climate effects are predicted to occur over decades and this could allow time to develop and implement successful reintroductions of ABBs in northern areas that are not predicted to have climate related limitations for ABB populations. For example, areas near the Great Lakes and the Atlantic coast are predicted to have less severe climate changes due to the moderating effect of large nearby waterbodies. Many of these areas are within the historic range, but there are no known ABB populations near these areas and little potential for ABBs to naturally reestablish populations there.

Despite predicted climate effects, efforts to reestablish ABB populations with adequate resiliency, representation and redundancy could be attempted in suitable climate-safe areas. To maintain existing levels of representation and redundancy, at least 2-3 new large populations (for moderate emissions climate effects or 5-6 populations for high emissions climate effects) would need to be established in climate safe areas and these populations would need to include representation of all existing genetic and ecological diversity in the current ABB populations. These reintroduced populations would provide insurance for long-term climate changes. The recent success of Missouri reintroduction efforts provides some evidence that this alternative scenario has potential, but there are multiple conditions and issues that would need to be addressed.

1. We do not know why the ABB was extirpated from these potential reintroduction sites or if any limiting factors have changed. Research related to potential limiting factors, such as carrion sources, competition, and genetics would need to be initiated for any reintroduction site.
2. We do not have agreements with the appropriate states or Canadian provinces to initiate or implement these reintroductions. Establishing experimental populations may be required.
3. We do not know if these reintroductions would be successful or if resources are available to initiate and maintain them. Previous reintroduction attempts have had mixed success (see Chapter 4, section 4.5). Reintroductions appear to require large numbers of ABBs and would involve moving wild or captive raised beetles. Methods have been developed for captive propagation and some captive populations are being maintained. However, the Nantucket Island introduction has demonstrated that the appropriate carrion resources must be present to maintain introduced populations, unless continued provisioning of carcasses is incorporated into management.

5.5.3.4 Summary of Historical Range Decline and Implications

The American Burying Beetle Recovery Plan (USFWS 1991) and the 5-year Status Review of the species (USFWS 2008a) identify the following factors as potential threats to ABB: direct habitat loss and alteration, increase in competition for prey, inter and intra-specific competition, increase in edge habitat, decrease in abundance of prey, loss of genetic diversity in isolated populations, disease/pathogens, DDT, agricultural and grazing practices, and invasive species. None of these factors alone adequately explain why ABBs declined over much of their historic range, while congeneric species remain relatively common range wide [there are eight sympatric congeners which are not in peril (Sikes and Raithel 2002, entire)].

The prevailing theory regarding the ABB's decline over a large portion of their historical range is habitat change (USFWS 1991, p 20, Sikes and Raithel 2002, entire) which: (1) reduced the carrion prey base of the appropriate size for ABB reproduction, and (2) increased the vertebrate scavenger competition for this resource (Kozol 1995, p 170; Lomolino and Creighton 1996, entire; Ratcliffe 1996; Amaral et al. 1997, p. 123–124; Bedick et al. 1999, p. 179; Creighton et al. 2009, p. 40). Although much of the evidence suggesting the reduction of carrion resources as a primary mechanism of decline is circumstantial, this hypothesis fits the temporal and geographical pattern of the disappearance of ABBs, and is sufficient to explain why ABBs declined while related species did not.

In addition to known risk factors, we need to consider the history of potential unknown or uncertain factors related to the decline and probable extirpation of most of the eastern portion of the ABB's historic range. The potential risks are discussed in chapter 3 and the potential causes for previous declines are thoroughly discussed in Sikes and Raithel 2002. We agree with the conclusions in Sikes and Raithel 2002, but are not certain what caused the declines in most eastern ABB populations and not sure if those risks are still current risks. The relatively rapid decline in ABB populations occurred from the early 1900s to the 1970s and we have not documented any continuing declines in most of the existing ABB range since the 1980s. If the factors that caused the loss of nearly 90 percent of the range occurred within a 70 year window and were still in effect; why haven't we seen a continued decline in the remaining population during the subsequent 50 years? It is possible the reduction of carrion resources as a primary mechanism of decline is accurate and that appropriate carrion resources in the remaining or current range have not been affected in the same way and continue to support ABB populations. We have documented some declines in the Red River Analysis Area since 2005, but these declines do not appear to be related to habitat or carrion. Populations on large protected areas like Camp Maxey in Texas declined with no apparent habitat changes. There is some evidence that these declines are related to climate changes (see discussions in sections 4.4.2 and 5.4.2.1), but we cannot rule out other contributing causes.

APPENDIX A

Developing GIS Data Layers and Analysis for the American Burying Beetle Species Status Assessment February 2019

INTRODUCTION

Background

The American Burying Beetle (*Nicrophorus americanus;* hereafter ABB) once widely distributed throughout temperate North America, is now known to exist in widely dispersed populations within the Great Plains (United States) and on Nantucket and Block islands (hereafter New England), off of Rhode Island (United States). The species was listed as endangered in 1989. Habitat loss and fragmentation are the primary drivers for its population decline (USFWS, 1991).

Purpose

This GIS analysis is to examine the current condition of the land cover within specified areas of the known populations, within the Great Plains and New England. As part of this effort, all presence/absence survey data (spatial and tablature) from multiple sources, dates, and locations were assembled into one normalized geographic dataset. All information and results generated from this analysis will be discussed in the formal Species Status Assessment (SSA) document. This report will be an appendix of the SSA document, and will limit discussions to geoprocessing methods and any other technical procedures applied to spatial data.

Study Area/Analysis Areas

The current area for this analysis was developed from available existing presence/absence survey data collected throughout the last century. Positive (present) survey points were buffered (then dissolved) in a GIS, to 30 kilometers (potential moving distance; Bedick et al. 1999, Creighton and Schnell, 1998, Jurzenski 2012, USFWS, 2014) to create large polygons (see SSA report, figure 2-6 and 5-1). These polygons will be the confines of the current condition land cover analysis. These areas were further subdivided based on general physiographic features into smaller Analysis Areas to provide a smaller, regional analysis. These smaller areas also expedite the geoprocessing routines for the GIS (see SSA Report – Chapter 4).

Data Limitations

All source landcover/ownership datasets used were developed by entities outside the USFWS. All these datasets are publicly available. The quality and accuracy of these data (ecological and spatial) may vary. Remotely sensed data products and large national datasets may contain inherent errors of omission and commission. Current land cover/ownership status may differ from the data displayed in the analysis. Actual, on-the-ground, quality and/or condition of mapped cover types is not addressed. No field verification or reviews of ancillary datasets/aerial imagery were done to verify the accuracy of the data. Raster land cover data has a minimum spatial resolution of 30 meters. These datasets, the analysis, and all maps/products created from it are subject to change.

Projections and Transformations

For this project, all data was projected into North American Albers Equal Area Conic, North American Datum (NAD) 1983. Typically, the raster datasets are downloaded in WGS 84, or other geographic coordinate systems. Re-projecting to Albers does slightly alter the shape of the pixels, but the change is nearly proportional, so there is negligible effect to the acreage of each pixel.

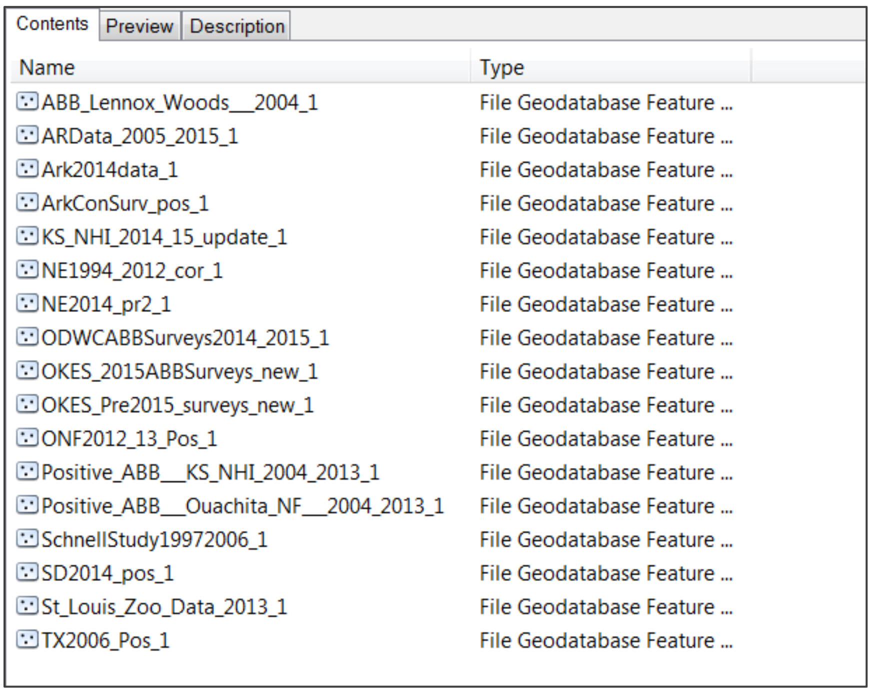
GIS Platform
All GIS analysis and mapping work was done using ArcGIS 10.3.

DATA AND SPATIAL ANALYSIS

GIS Analysis, Phase I: Presence/Absence Survey Data Collection Normalization (Great Plains only)

Normalization Process

1. All ES office ABB data was imported into a feature dataset with the appropriate coordinate system to normalize locational data in the spatial extent. North America Albers Equal Area Conic was used to minimize distortion over the large area necessary to display the data. This projection is used by the USGS and US Census Bureau. The following original shapefiles were used (Figure X):


Contents | Preview | Description

Name	Type
ABB_Lennox_Woods__2004_1	File Geodatabase Feature ...
ARData_2005_2015_1	File Geodatabase Feature ...
Ark2014data_1	File Geodatabase Feature ...
ArkConSurv_pos_1	File Geodatabase Feature ...
KS_NHI_2014_15_update_1	File Geodatabase Feature ...
NE1994_2012_cor_1	File Geodatabase Feature ...
NE2014_pr2_1	File Geodatabase Feature ...
ODWCABBSurveys2014_2015_1	File Geodatabase Feature ...
OKES_2015ABBSurveys_new_1	File Geodatabase Feature ...
OKES_Pre2015_surveys_new_1	File Geodatabase Feature ...
ONF2012_13_Pos_1	File Geodatabase Feature ...
Positive_ABB__KS_NHI_2004_2013_1	File Geodatabase Feature ...
Positive_ABB__Ouachita_NF__2004_2013_1	File Geodatabase Feature ...
SchnellStudy19972006_1	File Geodatabase Feature ...
SD2014_pos_1	File Geodatabase Feature ...
St_Louis_Zoo_Data_2013_1	File Geodatabase Feature ...
TX2006_Pos_1	File Geodatabase Feature ...

2. When merged, all shapefiles together contained over 70+ fields, due to data collection techniques that varied across time. Rather than picking existing fields, new fields were created to then populate with existing data. The following fields were created and populated (Table 1):

Field	Description
a_county_	County original data was recorded in**
a_dataset_	Original dataset
a_date_	Date - if only one date given
a_date_end_	Date end of surveys if given
a_date_start_	Date start of surveys if given
a_general_hab_	General habitat from original dataset
a_landclass_	Landclass of survey site from original dataset
a_landclass_veg_	Vegetation of survey site from original dataset

a_lat_	Latitude in decimal degrees
a_long_	Longitude in decimal degrees
a_method_	Survey method from original dataset
a_pos_neg_ABB_	Binary code of presense (1) or absense (0) from modified from original dataset
a_sex_	Sex of ABB trapped from original dataset
a_soil_	Soil type from original dataset
a_state_	State original data was recorded in**
a_surveyor_	Surveyor of original dataset
a_TotABB_	Total number of ABB from original dataset
a_trap_surv_num_	Trap number or survey site number from original dataset
a_year_	Year of data collection for original dataset
EVT_GP_N	Merged landclass value from LANDFIRE_LC data
Acres	Patch size, in acres, of landclass polygon
Sq_Miles	Patch size, in square miles, of landclass polygon
	****Corrected based on location of point data**

Table 1. Attributes for LANDFIRE dataset.

3. Many of the fields contain null values because the original dataset did not have these data fields populated.
4. Many original fields were dropped due to the specific nature or formatting with which the data was collected. For example, some datasets had a matrix of days in which surveys were completed. These data are preserved in the original datasets but became too cumbersome to normalize across all datasets.
5. Final field selection was based on which fields were most likely important to capture in reference to presence absence data.

<u>Data Anomalies</u>

1. Not all original datasets contained both presence and absence recorded data. Therefore, the master dataset contains all presence data recorded but only a portion of the absence data collected. Rectifying this would require locating missing portions of the datasets that only contained presence data.
2. Some datasets contained data that overlapped other datasets. To rectify this, ArcGIS tool "Find Identical" was used to locate data points that contained the same spatial location, as well as the same date. QA/QC was then conducted manually to compare identified records to determine if the data points were indeed identical.
   a. Multiple identical data points were located; however, less than 300 were true duplicates. This is due to the limitation of the ArcGIS tool to only be able to sort on a few fields.

GIS Analysis, Phase II: Current Condition of Land Cover within the Analysis Areas (Great Plains)

<u>Data Source</u>

Next, an examination of land cover data, looking at a depiction of current condition, as it relates to ABB suitability was undertaken. For this effort, USGS LANDFIRE 2012, Existing Vegetation Type (EVT) was used. This is a publicly available dataset that can be downloaded from the USGS LANDFIRE website. The spatial resolution of this data is 30 meters.

Ranking

Based on the land cover classification, Biologists determined a generalized suitability ranking and physiographic description for each classification. The suitability ranking was primarily based on the assumption of human impact on each classification category. There is collateral information within the data table that provides generalized information on natural condition and human disturbance (See Appendix A for complete table.).

Within the LANDFIRE data table, each land cover class was given a ranking descriptor (FWS_Condition) based on that information and expert opinion from Service Biologists:

Favorable - Land cover types with suitable soils and vegetation to support all or critical portions of the ABB life cycle. Favorable lands may range from high to low quality ABB habitat, but most of these lands should be capable of supporting ABB populations. The ABB uses a wide variety of habitats and favorable land cover types including multiple forest, savanna, shrub, and grassland/herbaceous land covers.

Conditional - Land cover types that can be favorable under some conditions and unsuitable under others. For example, most pasture land in southern plains analysis areas may be favorable habitat if grazing is light to moderate or infrequently mowed, but the same area may be unsuitable if it is heavily grazed or frequently mowed. Fields managed for hay can be unsuitable habitat when the vegetation is mowed at short heights, but can be favorable habitat between cuttings when the grass/hay is tall enough to provide suitable habitat for birds and mammals that are carrion sources for ABBs. Wetlands are another example. They may be unsuitable under flood conditions, but very important habitat during droughts, given that ABBs need moist soils.

Marginal – Land cover types that can provide limited habitat for some portions of the ABB life cycle. Examples include land covers that have poor or thin soils (such as barren lands) that make them unsuitable for reproduction, but may provide habitat for day use or help support potential carrion species to some degree.

Unsuitable – Land cover types that do not provide habitat that would be favorable for any portion of the ABB life cycle (such as open water or highly developed urban lands).

Landcover Analysis Limitations

This generalized land cover analysis was not intended to describe or predict where beetles might occur, but to take into account the current state of land use and land cover types and their relationship to human impact and development. There may be many other factors to examine and/or predict where beetles may occur, including soil type/material information and meteorological/climate information. For this analysis, these factors were not considered.

GIS Analysis, Phase III: Extent of Urbanization/Development

To further grasp a sense of the extent and nearby influence of urban development within the Analysis Areas, a road density surface was created to identify areas with the highest densities of roads.

Density Surface Construction

A density surface is a raster layer, created in ArcMap, to represent the relative density of specific features (points, lines, etc...). It can be a useful representation of large datasets (i.e.; a roads layer) where the actual features are not needed, just where they occur most frequently.

Density surfaces can easily be created in ArcMap by using the *Spatial Analyst* tool set in ArcToolbox. For this exercise, the U.S. Census Bureau 2015 TIGER roads layer was used. A large area, covering most of the central U.S. was extracted from the TIGER layer. This area covers far beyond the Analysis Areas. This was done to provide an accurate surface creation at the edges of the Analysis Areas. After the raster surface is created, it is then clipped to the Analysis Areas boundaries.

The parameters for the density surface were as follows;

<u>Central U.S. Study Areas</u>
Tool: Line Density, Spatial Analyst
Pixel Size (output): 500 meters
Search Radius: 5000 meters

The resulting raster surface was then classified (in Layer Properties, Symbology) with 30 classes at Equal Intervals. This provides a detailed stratification of 30 relative classes from no relative density to high relative density. This raster surface is then converted to a vector file so it can be analyzed with other vector layers. For this analysis, only the highest density category classes were used. This was done to recognize only human population centers. Selecting only these highest density categories, purposefully excludes other situations which can show high density road networks; such as logging and rural road grid systems, which are thought not to have a significant impact on the ABB.

<u>Geoprocessing; Data Layer Union</u>
This vectorized road density layer was then "Unioned" (a GIS geoprocessing tool, which analyzes overlapping layers) with the ABB land cover suitability layer, showing where the ABB class types are affected areas of higher development stress.

Union calculates the geometric union of any number of feature classes and feature layers. All input feature classes or feature layers must be polygons. The output feature class will contain polygons representing the geometric union of all the inputs as well as all the fields from all the input feature classes. See below for examples of how attribute values are assigned to the output features (Esri, Inc.).

Union does the following:
- Determines the spatial reference for processing. This will also be the output spatial reference. For details on how this is done, see Spatial Reference. All the input feature classes are projected (on the fly) into this spatial reference.
- Cracks and clusters the features. Cracking inserts vertices at the intersection of feature edges; clustering snaps together vertices that are within the x,y tolerance.
- Discovers geometric relationships (overlap) between features from all feature classes.
- Writes the new features to the output.

As mentioned above, this process does slightly alter the shapes of the new (unioned) polygons created, which can slightly alter the calculated acreages of the polygons (relative to pre-union acreage). This change is negligible, usually much less than one percent.

<u>Weighted Ranking of ABB Landcover Suitability Layer with Developed Area Layer</u>
The result of this union is reflected in the table below (Table 2). Any areas of the landcover suitability layer, that were within the urbanization/developed layer, were downgraded in suitability ranking.

Urbanization /Developed Area Layer	ABB Landcover (Habitat) Suitability Layer			
	Favorable	Conditional	Marginal	Unsuitable
No Development Impact	*Favorable*	*Conditional*	*Marginal*	*Unsuitable*
Development Impact	*Marginal*	*Marginal*	*Unsuitable*	*Unsuitable*

Table 2: ABB Habitat Suitability Matrix.

Results
The formal SSA document will further describe development and rationale of the landcover suitability classification and rankings, as well as providing the results/calculated areas of all the different suitability types.

GIS Analysis, Phase IV: Protection Status

A spatial representation of existing level of protection was developed to analyze the extent and distribution of areas, based on land ownership, indicating portions of the suitability layer which may have some protection for ABB. The land ownership data was "unioned" with the land cover suitability layer, which gives an ownership designation to each of the suitability layer polygons.

Data Source
Conservation Biology Institute (CBI); Protected Areas Database, U.S., CBI Edition, v2
Land Ownership, U.S.

Land ownership/Management and Protection Status
Protected Areas Database, U.S., CBI Edition, v2. Though the union process, the CBI land ownership data was used to give each suitable habitat polygon an ownership designation. Also, each ownership category was then given a management, or protection status designation, developed by USFWS biologists, to further describe the types, or levels, of protection occurring for that specific polygon. It was important to get a sense of not only areas there are considered protected by local, state or federal jurisdiction, but also to quantify areas where urban growth/development could occur in the long-term future.

Ownership Category:
Federal Government: Owned by a Federal agency (NPS, USFS, BLM, etc.)
State Government: Owned by state of Arizona agency (parks, historic areas, trust lands etc.)
Local Governments: Owned by county or municipal governments (parks, open spaces, facilities, etc.)
Private: Owned by private citizens or entities.
Private Conservation: Owned by non-governmental conservation entities (TNC, etc.)
Tribal: Sovereign or trust Native American territories.
None: Ownership information not available.

Assigned Protection Designation:
Managed: Land managed for wildlife habitat or low impact human activity (wilderness areas, wildlife management areas, preserves, some parks and monuments).
Multi-Use: Public land owned by public agencies (vast majority is Federal ownership), which allow more intrusive human activities (motorized vehicles, resource extraction, grazing, etc.) but provide some wildlife management benefits in addition to other uses.
Other: Highly variable or unknown protection status (i.e.; municipal, state, etc...).
Tribal: Native American holding, level and type of protection may vary.
Unprotected: Privately owned land.
N/A: Ownership information not available.

Results
All results and acreage calculations for the union of the ownership/protection status and the landcover suitability layer are discussed in the SSA Report. The Feature Class data table will contain all of the original source land cover types, FWS-developed habitat suitability ranking, indicated impact from development, land ownership, and protection designation for each polygon. A summary field (Cond_pro) will provide a quick determination for each polygon based on a combination of the suitability and assigned protection designations.

GIS Analysis, Phase V: Current Condition of Land Cover on Block and Nantucket Islands
Data Source
Land cover data (vector) was downloaded from the following State websites;
Rhode Island: *Rhode Island Geographic Information System (http://www.rigis.org/data/env)*

A. *Land Cover & Land Use 2011; (rilc11d.zip)*
B. *Ecological Communities Classification; (RIECC11.zip)*

Massachusetts: *Mass.gov, Administration and Finance, Research & Technology, MassGIS Datalayers (http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/layerlist.html)*

A. *Land Use (2005); (landuse2005_poly.zip)*

Ranking
Since the Atlantic Island populations are well-documented, no GIS/modeling effort was conducted, beyond assigning a suitability ranking. Each land cover type was assigned the same suitability ranking as the Great Plains areas (see; GIS Analysis, Phase II: Current Condition of Land cover within the Analysis Areas **(Great Plains)**). These determinations were made through expert opinion by Region 5 USFWS Biologists. No further analysis was conducted on these datasets.

Results
Only cartographic products were generated for the SSA report. Any other acreage or scenario discussions will be done in the SSA report.

GIS Analysis, Phase VI: Kriging Interpolation

Data Source
Presence/Absence Survey Data for the ABB, as described in Phase I above.

Kriging Analysis Methods
Kriging interpolations can be created in ArcMap by using the Spatial Analysis tool set in ArcToolbox. As described in ArcGIS 10.4.1 help "Kriging is an advanced geostatistical procedure that generates an estimated surface from a scattered set of points with z-values. Unlike other interpolation methods in the Interpolation toolset, to use the Kriging tool effectively involves an interactive investigation of the spatial behavior of the phenomenon represented by the z-values before you select the best estimation method for generating the output surface."

The parameters for the density surface were as follows;

Input point features: ABB Survey presence/absence data
Z value field: Postive/negative survey results (0=negative, 1=positive)
Kriging method: ordinary
Semivariogram model: spherical
Output cell size: 0.02
Number of points: 12

Maximum distance: none entered

Results
Although Kriging analyses can used to determine probability of occurrence, due to the limitations of our survey data we used the Kriging analysis only as an observational tool to visually compare areas of differing capture rates to determine a broad assessment of ABB distributions within each analysis area.

GIS Analysis, Phase VII: Future Climate Scenarios

Data Source

MACAv2-METDATA, Multi-Model Mean – Climate forcings in the MACAv2-LIVNEH were drawn from a statistical downscaling of global climate model (GCM) data from the Coupled Model Intercomparison Project 5 (CMIP5, Taylor et al. 2010) utilizing a modification (Hegewisch, Abatzoglou, in prep.) of the Multivariate Adaptive Constructed Analogs (MACA, Abatzoglou and Brown, 2012) method with the Livneh (Livneh et.al.,2013) observational dataset as training data.
http://maca.northwestknowledge.net/index.php

Raster Display Method

MACAv2-METDATA, Multi-Model Mean raster data was obtained for projected change in summer (Jun-July-Aug) maximum temperature for two emission scenarios (RCP 4.5 and 8.5) for three different time periods (2010-2039, 2040-2069, 2070-2099).

Raster colors for differing temperatures and for the temperature threshold analysis were created by using symbology in Layer Options.

Results
All results (in cartographic format) are displayed in Chapters 3 and 5 of the SSA Report – Figures 3-1, 5-4, 5-5, 5-6, and 5-7.

CONCLUSION

This report is a brief summation of the GIS data analysis (data layer usage and geoprocessing techniques) devised to help provide a spatial understanding of the location and extent of potentially suitable habitat for ABB and to analyze how specific threats may affect these areas. The larger SSA report will provide a more detailed discussion on the actual results and summaries of the various threat analysis scenarios.

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Jurzenski, J. 2012. Factors affecting the distribution and survival of endangered American burying beetles, *Nicrophorus americanus* Olivier. Dissertations and Student Research in Entomology. Paper 20. http://digitalcommons.unl.edu/entomologydiss/20

U.S. Fish and Wildlife Service (USFWS). 1991. American burying beetle (*Nicrophorus americanus*) recovery plan. Newton Corner, Massachusetts. 80 pp.

U.S. Fish and Wildlife Service (USFWS). 2014. American Burying Beetle (*Nicrophorus americanus - Oliver*). Tulsa, Oklahoma. 29 pp.

ONLINE RESOURCES

Conservation Biology Institute,
Protected Areas Database of the US, PAD-US (CBI Edition)
https://consbio.org/products/projects/pad-us-cbi-edition
Metadata:
https://d2k78bk4kdhbpr.cloudfront.net/media/content/files/PADUS_CBIEdition_V2_Metadata.pdf

Rhode Island Geographic Information System; http://www.rigis.org/data/env
Land Cover & Land Use 2011 (rilc11d.zip)
Metadata: http://www.rigis.org/geodata/plan/rilc11d.html
Ecological Communities Classification (RIECC11.zip)
Metadata: http://www.rigis.org/geodata/plan/rilc11d.html

State of Massachusetts, MassGIS Datalayers;
http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/layerlist.html
Land Use (2005); (landuse2005_poly.zip)
Metadata: http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/lus2005.html

U.S. Census Bureau, TIGER Products (Roads for urban area density surface)
https://www.census.gov/geo/maps-data/data/tiger.html
Metadata:
http://www2.census.gov/geo/pdfs/maps-data/data/tiger/tgrshp2015/TGRSHP2015_TechDoc.pdf

U.S. Geological Survey LANDFIRE; http://landfire.gov/
Existing Vegetation Type (EVT) Metadata:
http://landfire.cr.usgs.gov/distmeta/servlet/gov.usgs.edc.MetaBuilder?TYPE=HTML&DATASET=FBI

Table 3: Landfire Land Cover Classes and their Associated Suitability Ranking (Great Plains only)

Landfire Value	Landfire CLASSNAME	FWS_Condition
3412	North-Central Interior Sand and Gravel Tallgrass Prairie	Conditional
3534	Managed Tree Plantation-Northern and Central Hardwood and Conifer Plantation Group	Marginal
3941	Western Cool Temperate Undeveloped Ruderal Evergreen Forest	Favorable
3951	Eastern Cool Temperate Undeveloped Ruderal Evergreen Forest	Favorable
3955	Eastern Warm Temperate Undeveloped Ruderal Deciduous Forest	Favorable
3094	Western Great Plains Sandhill Shrubland	Favorable
3310	North-Central Interior Dry-Mesic Oak Forest and Woodland	Favorable
3367	Ozark-Ouachita Shortleaf Pine Forest and Woodland	Favorable
3383	Edwards Plateau Limestone Woodland	Favorable
3480	Gulf and Atlantic Coastal Plain Swamp Systems	Marginal
3582	Ozark-Ouachita Oak Forest and Woodland	Favorable
3059	Southern Rocky Mountain Pinyon-Juniper Woodland	Marginal
3085	Northwestern Great Plains Shrubland	N/A
3148	Western Great Plains Sand Prairie Grassland	Conditional
3149	Western Great Plains Shortgrass Prairie	Favorable
3162	Western Great Plains Floodplain Forest and Woodland	Favorable
3181	Introduced Upland Vegetation-Annual Grassland	Conditional
3182	Introduced Upland Vegetation-Perennial Grassland and Forbland	Conditional
3191	Recently Logged-Herb and Grass Cover	Conditional
3192	Recently Logged-Shrub Cover	Favorable
3195	Recently Burned-Herb and Grass Cover	Conditional
3204	Western Great Plains Mesquite Shrubland	Unsuitable
3253	Western Great Plains Floodplain Shrubland	Favorable
3254	Western Great Plains Floodplain Herbaceous	Favorable
3274	Central Interior and Appalachian Floodplain Herbaceous	Unsuitable
3291	Central Interior Highlands Calcareous Glade and Barrens Herbaceous	Marginal
3292	Open Water	Unsuitable
3294	Barren	Marginal
3296	Developed-Low Intensity	Unsuitable
3297	Developed-Medium Intensity	Unsuitable
3298	Developed-High Intensity	Unsuitable
3299	Developed-Roads	Unsuitable
3300	Central Interior and Appalachian Riparian Herbaceous	Favorable
3304	Ozark-Ouachita Dry-Mesic Oak Forest	Favorable
3308	Crosstimbers Oak Forest and Woodland	Favorable
3314	North-Central Interior Maple-Basswood Forest	Marginal
3334	Ozark-Ouachita Mesic Hardwood Forest	Favorable
3364	Ozark-Ouachita Dry Oak Woodland	Marginal

3385	Western Great Plains Wooded Draw and Ravine	Favorable
3401	Central Interior Highlands Calcareous Glade and Barrens Woodland	Marginal
3415	Arkansas Valley Prairie and Woodland	Favorable
3421	Central Tallgrass Prairie	Conditional
3422	Texas Blackland Tallgrass Prairie	Conditional
3423	Southeastern Great Plains Tallgrass Prairie	Conditional
3462	West Gulf Coastal Plain Seepage Swamp and Baygall	Conditional
3471	Central Interior and Appalachian Floodplain Forest	Favorable
3472	Central Interior and Appalachian Riparian Forest	Favorable
3495	Western Great Plains Depressional Wetland Systems	Favorable
3519	East-Central Texas Plains Post Oak Savanna and Woodland	Favorable
3523	Edwards Plateau Dry-Mesic Slope Forest and Woodland	Favorable
3529	Ruderal Upland Herbaceous	Favorable
3535	Managed Tree Plantation-Southeast Conifer and Hardwood Plantation Group	Marginal
3539	Modified/Managed Northern Tallgrass Grassland	Conditional
3540	Modified/Managed Southern Tallgrass Grassland	Conditional
3564	Modified/Managed Southern Tallgrass Shrubland	Favorable
3583	Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland	Favorable
3900	Western Cool Temperate Urban Deciduous Forest	Marginal
3901	Western Cool Temperate Urban Evergreen Forest	Marginal
3902	Western Cool Temperate Urban Mixed Forest	Marginal
3903	Western Cool Temperate Urban Herbaceous	Unsuitable
3904	Western Cool Temperate Urban Shrubland	Marginal
3905	Eastern Cool Temperate Urban Deciduous Forest	Marginal
3906	Eastern Cool Temperate Urban Evergreen Forest	Marginal
3907	Eastern Cool Temperate Urban Mixed Forest	Marginal
3908	Eastern Cool Temperate Urban Herbaceous	Unsuitable
3909	Eastern Cool Temperate Urban Shrubland	Marginal
3920	Western Cool Temperate Developed Ruderal Deciduous Forest	Unsuitable
3924	Western Cool Temperate Developed Ruderal Grassland	Unsuitable
3930	Eastern Cool Temperate Developed Ruderal Deciduous Forest	Unsuitable
3931	Eastern Cool Temperate Developed Ruderal Evergreen Forest	Unsuitable
3932	Eastern Cool Temperate Developed Ruderal Mixed Forest	Unsuitable
3933	Eastern Cool Temperate Developed Ruderal Shrubland	Unsuitable
3934	Eastern Cool Temperate Developed Ruderal Grassland	Unsuitable
3954	Eastern Cool Temperate Undeveloped Ruderal Grassland	Favorable
3964	Western Cool Temperate Row Crop	Unsuitable
3965	Western Cool Temperate Close Grown Crop	Unsuitable
3966	Western Cool Temperate Fallow/Idle Cropland	Favorable
3967	Western Cool Temperate Pasture and Hayland	Conditional
3968	Western Cool Temperate Wheat	Unsuitable

3970	Eastern Cool Temperate Orchard	Unsuitable
3973	Eastern Cool Temperate Row Crop - Close Grown Crop	Unsuitable
3974	Eastern Cool Temperate Row Crop	Unsuitable
3975	Eastern Cool Temperate Close Grown Crop	Unsuitable
3976	Eastern Cool Temperate Fallow/Idle Cropland	Favorable
3977	Eastern Cool Temperate Pasture and Hayland	Conditional
3978	Eastern Cool Temperate Wheat	Unsuitable
3997	Eastern Warm Temperate Pasture and Hayland	Conditional
3312	Ouachita Montane Oak Forest	Marginal
3268	Eastern Great Plains Tallgrass Aspen Shrubland	N/A
3331	Eastern Great Plains Tallgrass Aspen Forest and Woodland	N/A
3007	Western Great Plains Sparsely Vegetated Systems	Unsuitable
3013	Western Great Plains Dry Bur Oak Forest and Woodland	Unsuitable
3049	Rocky Mountain Foothill Limber Pine-Juniper Woodland	Unsuitable
3054	Southern Rocky Mountain Ponderosa Pine Woodland	N/A
3072	Wyoming Basins Dwarf Sagebrush Shrubland and Steppe	N/A
3081	Inter-Mountain Basins Mixed Salt Desert Scrub	N/A
3117	Southern Rocky Mountain Ponderosa Pine Savanna	N/A
3132	Central Mixedgrass Prairie Grassland	Conditional
3141	Northwestern Great Plains Mixedgrass Prairie	Conditional
3150	Western Great Plains Tallgrass Prairie	Conditional
3179	Northwestern Great Plains-Black Hills Ponderosa Pine Woodland and Savanna	Unsuitable
3183	Introduced Upland Vegetation-Annual and Biennial Forbland	Conditional
3194	Ruderal Upland-Treed	Favorable
3207	Central Mixedgrass Prairie Shrubland	Favorable
3209	Western Great Plains Sand Prairie Shrubland	Favorable
3212	Western Great Plains Sandhill Grassland	Favorable
3273	Eastern Great Plains Floodplain Herbaceous	Favorable
3275	Central Interior and Appalachian Floodplain Shrubland	Unsuitable
3295	Quarries-Strip Mines-Gravel Pits	Marginal
3311	North-Central Interior Dry Oak Forest and Woodland	Favorable
3319	Central Interior and Appalachian Riparian Shrubland	Favorable
3323	West Gulf Coastal Plain Mesic Hardwood Forest	Favorable
3332	Gulf and Atlantic Coastal Plain Floodplain Herbaceous	Favorable
3348	West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	Favorable
3359	Gulf and Atlantic Coastal Plain Floodplain Shrubland	Favorable
3363	Central Interior Highlands Dry Acidic Glade and Barrens	Marginal
3371	West Gulf Coastal Plain Pine Forest	Favorable
3378	West Gulf Coastal Plain Sandhill Shortleaf Pine Forest and Woodland	Favorable
3428	West Gulf Coastal Plain Northern Calcareous Prairie	Conditional
3429	West Gulf Coastal Plain Southern Calcareous Prairie	Conditional

3451	West Gulf Coastal Plain Wet Longleaf Pine Savanna and Flatwoods	Marginal
3458	West Gulf Coastal Plain Pine Flatwoods	Favorable
3469	Eastern Great Plains Floodplain Woodland	Favorable
3473	Gulf and Atlantic Coastal Plain Floodplain Forest	Favorable
3474	Gulf and Atlantic Coastal Plain Small Stream Riparian Woodland	Favorable
3479	Central Interior and Appalachian Swamp Forest	Conditional
3482	Great Plains Prairie Pothole	N/A
3488	Eastern Great Plains Wet Meadow-Prairie-Marsh	Favorable
3493	Central Interior and Appalachian Herbaceous Wetlands	Conditional
3497	Central Interior and Appalachian Sparsely Vegetated Systems	Unsuitable
3506	West Gulf Coastal Plain Nonriverine Wet Hardwood Flatwoods	Favorable
3507	Ozark-Ouachita Shortleaf Pine-Bluestem Woodland	Favorable
3528	Ruderal Upland Shrubland	Favorable
3531	Ruderal Upland Forest	Favorable
3532	Ruderal Forest-Northern and Central Hardwood and Conifer	Favorable
3573	Gulf and Atlantic Coastal Plain Small Stream Riparian Herbaceous	Favorable
3574	Gulf and Atlantic Coastal Plain Small Stream Riparian Shrubland	Favorable
3584	West Gulf Coastal Plain Hardwood Forest	Favorable
3585	West Gulf Coastal Plain Pine-Hardwood Forest	Favorable
3586	West Gulf Coastal Plain Sandhill Oak Forest and Woodland	Favorable
3587	West Gulf Coastal Plain Sandhill Oak and Shortleaf Pine Forest and Woodland	Favorable
3590	West Gulf Coastal Plain Hardwood Flatwoods	Favorable
3591	West Gulf Coastal Plain Pine-Hardwood Flatwoods	Favorable
3915	Eastern Warm Temperate Urban Urban Deciduous Forest	Marginal
3916	Eastern Warm Temperate Urban Urban Evergreen Forest	Marginal
3917	Eastern Warm Temperate Urban Urban Mixed Forest	Marginal
3918	Eastern Warm Temperate Urban Urban Herbaceous	Unsuitable
3919	Eastern Warm Temperate Urban Urban Shrubland	Unsuitable
3921	Western Cool Temperate Developed Ruderal Evergreen Forest	Unsuitable
3922	Western Cool Temperate Developed Ruderal Mixed Forest	Unsuitable
3923	Western Cool Temperate Developed Ruderal Shrubland	Unsuitable
3925	Western Warm Temperate Developed Ruderal Deciduous Forest	Unsuitable
3929	Western Warm Temperate Developed Ruderal Grassland	Unsuitable
3935	Eastern Warm Temperate Developed Ruderal Deciduous Forest	Unsuitable
3936	Eastern Warm Temperate Developed Ruderal Evergreen Forest	Unsuitable
3937	Eastern Warm Temperate Developed Ruderal Mixed Forest	Unsuitable
3938	Eastern Warm Temperate Developed Ruderal Shrubland	Unsuitable
3939	Eastern Warm Temperate Developed Ruderal Grassland	Unsuitable
3940	Western Cool Temperate Undeveloped Ruderal Deciduous Forest	Favorable
3943	Western Cool Temperate Undeveloped Ruderal Shrubland	Favorable
3944	Western Cool Temperate Undeveloped Ruderal Grassland	Favorable

3950	Eastern Cool Temperate Undeveloped Ruderal Deciduous Forest	Favorable
3952	Eastern Cool Temperate Undeveloped Ruderal Mixed Forest	Favorable
3953	Eastern Cool Temperate Undeveloped Ruderal Shrubland	Favorable
3956	Eastern Warm Temperate Undeveloped Ruderal Evergreen Forest	Favorable
3957	Eastern Warm Temperate Undeveloped Ruderal Mixed Forest	Favorable
3958	Eastern Warm Temperate Undeveloped Ruderal Shrubland	Favorable
3959	Eastern Warm Temperate Undeveloped Ruderal Grassland	Favorable
3960	Western Cool Temperate Orchard	Unsuitable
3963	Western Cool Temperate Row Crop - Close Grown Crop	Unsuitable
3983	Western Warm Temperate Row Crop - Close Grown Crop	Unsuitable
3984	Western Warm Temperate Row Crop	Unsuitable
3985	Western Warm Temperate Close Grown Crop	Unsuitable
3986	Western Warm Temperate Fallow/Idle Cropland	Favorable
3987	Western Warm Temperate Pasture and Hayland	Conditional
3988	Western Warm Temperate Wheat	Unsuitable
3990	Eastern Warm Temperate Orchard	Unsuitable
3993	Eastern Warm Temperate Row Crop - Close Grown Crop	Unsuitable
3994	Eastern Warm Temperate Row Crop	Unsuitable
3995	Eastern Warm Temperate Close Grown Crop	Unsuitable
3996	Eastern Warm Temperate Fallow/Idle Cropland	Favorable
3998	Eastern Warm Temperate Wheat	Unsuitable
3999	Eastern Warm Temperate Aquaculture	Unsuitable

APPENDIX B

Additional Climate Analyses
American Burying Beetle Species Status Assessment
February 2019

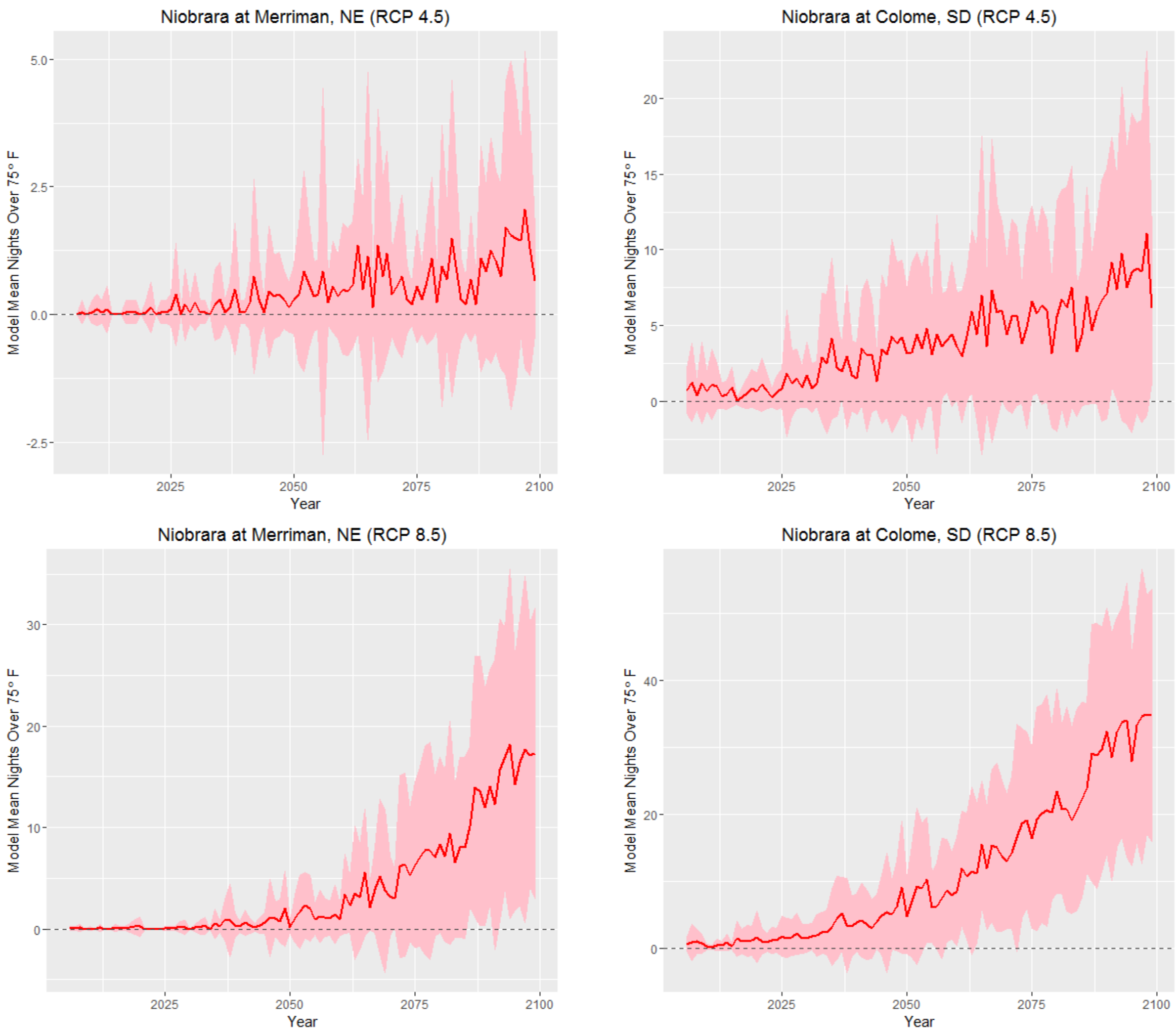

Figure A. The mean (red line) and standard deviation (pink shading) of 20 statistically downscaled climate change models for two locations (East = Colome, SD; West =Merriman, NE) within the Niobrara Analysis Area. Each graph shows the change over time in the mean number of nights with minimum temperatures greater than or equal to 75°F. American Burying Beetles in captivity cannot reproduce when temperatures exceed 75°F.

Figure B. The mean (red line) and standard deviation (pink shading) of 20 statistically downscaled climate change models for two locations (East = Amelia, NE; West = Thedford, NE) within the Sand Hills Analysis Area. Each graph shows the change over time in the mean number of nights with minimum temperatures greater than or equal to 75°F. American Burying Beetles in captivity cannot reproduce when temperatures exceed 75°F.

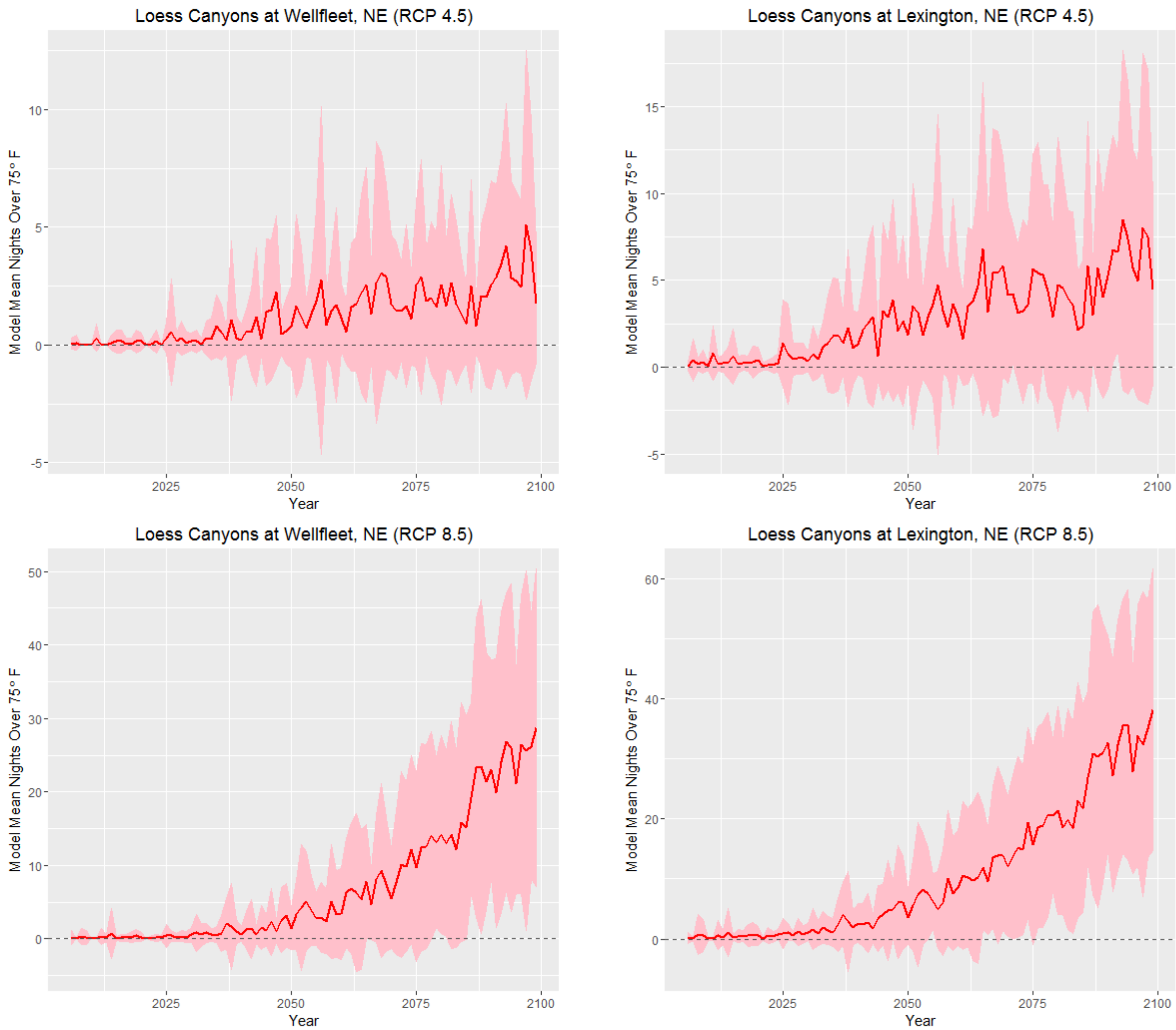

Figure C. The mean (red line) and standard deviation (pink shading) of 20 statistically downscaled climate change models for two locations (East = Lexington, NE; West = Wellfleet, NE) within the Loess Canyons Analysis Area. Each graph shows the change over time in the mean number of nights with minimum temperatures greater than or equal to 75°F. American Burying Beetles in captivity cannot reproduce when temperatures exceed 75°F.

Figure D. The mean (red line) and standard deviation (pink shading) of 20 statistically downscaled climate change models for two locations (East = Fredonia, KS; West = Webb City, OK) within the Flint Hills Analysis Area. Each graph shows the change over time in the mean number of nights with minimum temperatures greater than or equal to 75°F. American Burying Beetles in captivity cannot reproduce when temperatures exceed 75°F.

Figure E. The mean (red line) and standard deviation (pink shading) of 20 statistically downscaled climate change models for two locations (East = Van Buren, AR; West = Shawnee, OK) within the Arkansas River Analysis Area. Each graph shows the change over time in the mean number of nights with minimum temperatures greater than or equal to 75°F. American Burying Beetles in captivity cannot reproduce when temperatures exceed 75°F.

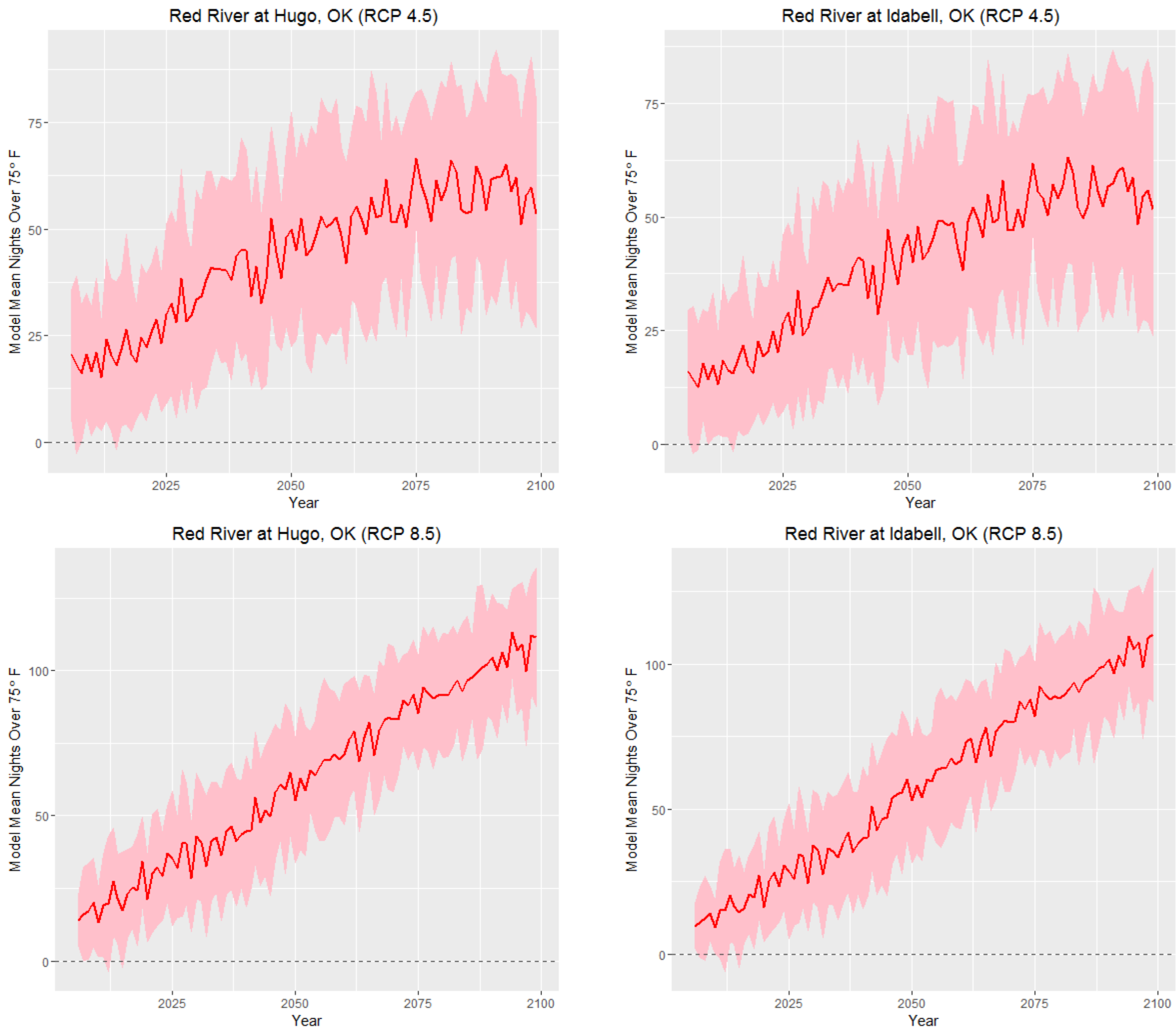

Figure F. The mean (red line) and standard deviation (pink shading) of 20 statistically downscaled climate change models for two locations (East = Idabell, OK; West = Hugo, OK) within the Red River Analysis Area. Each graph shows the change over time in the mean number of nights with minimum temperatures greater than or equal to 75°F. American Burying Beetles in captivity cannot reproduce when temperatures exceed 75°F.

Table A. Mean number nights above 75°F for each of the analysis areas during thirty year periods. RCP are Relative Concentration Pathways representing possible emission scenarios.

Analysis Area		Mean Number of Nights Above 75°F		
Nearest Town	RCP	2010 - 2039	2040 - 2069	2070 - 2099
Red River				
Idabell, OK	4.5	24.9	44.3	54.8
	8.5	26.9	61.3	94.6
Hugo, OK	4.5	28.8	47.9	58.3
	8.5	32.1	65.4	97.3
Arkansas River				
Van Buren, AR	4.5	22.1	38.8	48.5
	8.5	25.2	55.5	88.3
Shawnee, OK	4.5	30.1	46.9	56.0
	8.5	33.5	62.3	91.2
Flint Hills				
Freedonia, KS	4.5	14.5	27.4	34.6
	8.5	17.2	39.9	67.6
Webb City, OK	4.5	26.4	41.3	49.0
	8.5	29.5	54.7	82.1
Loess Canyons				
Lexington, NE	4.5	0.7	3.3	4.9
	8.5	1.0	7.3	24.8
Wellfleet, NE	4.5	0.2	1.4	2.3
	8.5	0.5	3.9	17.6
Sand Hills				
Amelia, NE	4.5	0.5	2.5	4.3
	8.5	0.8	6.1	21.7
Thedford, NE	4.5	0.1	0.6	1.2
	8.5	0.2	2.2	12.4
Niobrara				
Colome, SD	4.5	1.3	4.0	6.5
	8.5	1.7	8.4	24.7
Merriman, NE	4.5	0.1	0.5	0.9
	8.5	0.16	1.79	10.58

Table B. Results of linear regressions for predictions of change in nights above 75°F for each analysis area and emissions scenario.

Analysis Area Nearest Town	RCP	Regression Type	Intercept	Coefficient	R-Squared	*P*-value
Red River						
Idabell, OK	4.5	Ln-Linear	-25.92	0.0144	0.8323	< 0.0001
	8.5	Simple Linear	-2216.87	1.1088	0.9860	< 0.0001
Hugo, OK	4.5	Ln-Linear	-22.70	0.0129	0.8191	< 0.0001
	8.5	Simple Linear	-2134.74	1.0707	0.9828	< 0.0001
Arkansas River						
Van Buren, AR	4.5	Ln-Linear	-25.85	0.0143	0.8307	< 0.0001
	8.5	Simple Linear	-2058.70	1.0296	0.9850	< 0.0001
Shawnee, OK	4.5	Ln-Linear	-19.52	0.0113	0.8137	< 0.0001
	8.5	Simple Linear	-1880.91	0.9459	0.9806	< 0.0001
Flint Hills						
Freedonia, KS	4.5	Ln-Linear	-28.85	0.0156	0.8300	< 0.0001
	8.5	Simple Linear	-1637.89	0.8176	0.9695	< 0.0001
Webb City, OK	4.5	Ln-Linear	-19.44	0.0112	0.8182	< 0.0001
	8.5	Simple Linear	-1711.35	0.8601	0.9764	< 0.0001
Loess Canyons						
Lexington, NE	4.5	Simple Linear	-142.02	0.0706	0.7691	< 0.0001
	8.5	Ln-Linear	-83.26	0.0415	0.9701	< 0.0001
Wellfleet, NE	4.5	Simple Linear	-69.95	0.0347	0.6952	< 0.0001
	8.5	Ln-Linear	-80.95	0.0402	0.9509	< 0.0001
Sand Hills						
Amelia, NE	4.5	Simple Linear	-126.09	0.0626	0.8183	< 0.0001
	8.5	Ln-Linear	-83.41	0.0415	0.9743	< 0.0001
Thedford, NE	4.5	Simple Linear	-35.85	0.0178	0.6863	< 0.0001
	8.5	Ln-Linear	-76.11	0.0377	0.9285	< 0.0001
Niobrara						
Colome, SD	4.5	Simple Linear	-173.48	0.0864	0.8253	< 0.0001
	8.5	Ln-Linear	-75.75	0.0379	0.9732	< 0.0001
Merriman, NE	4.5	Simple Linear	-26.65	0.0132	0.5723	< 0.0001
	8.5	Ln-Linear	-71.37	0.0353	0.9056	< 0.0001

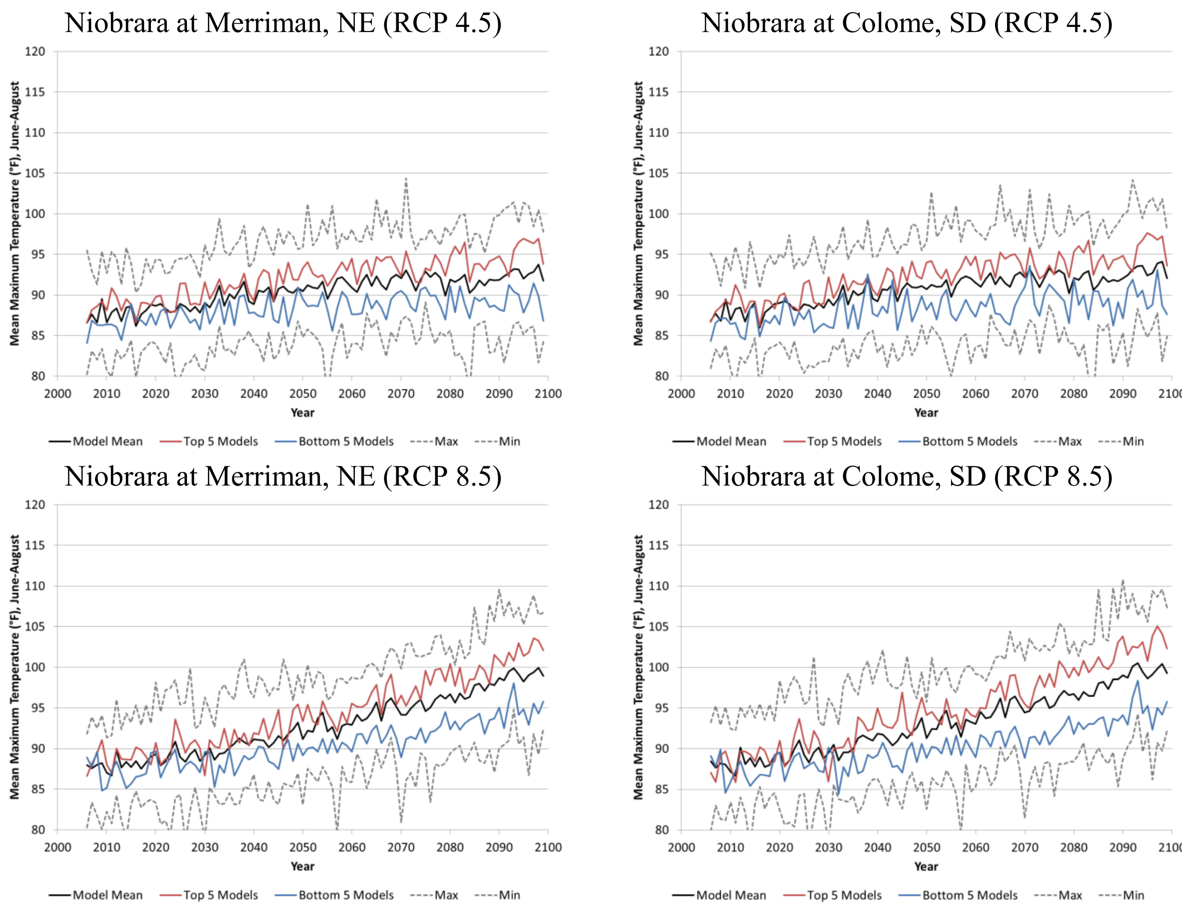

Figure G. The mean (black line), five mean warmest (red line), five mean coolest (blue line), and maximum and minimum values (grey dashed line) of 20 statistically downscaled climate change models for two locations (East = Colome, SD; West =Merriman, NE) within the Niobrara Analysis Area. Each graph shows the change over time in the mean maximum temperature for the months June, July, and August.

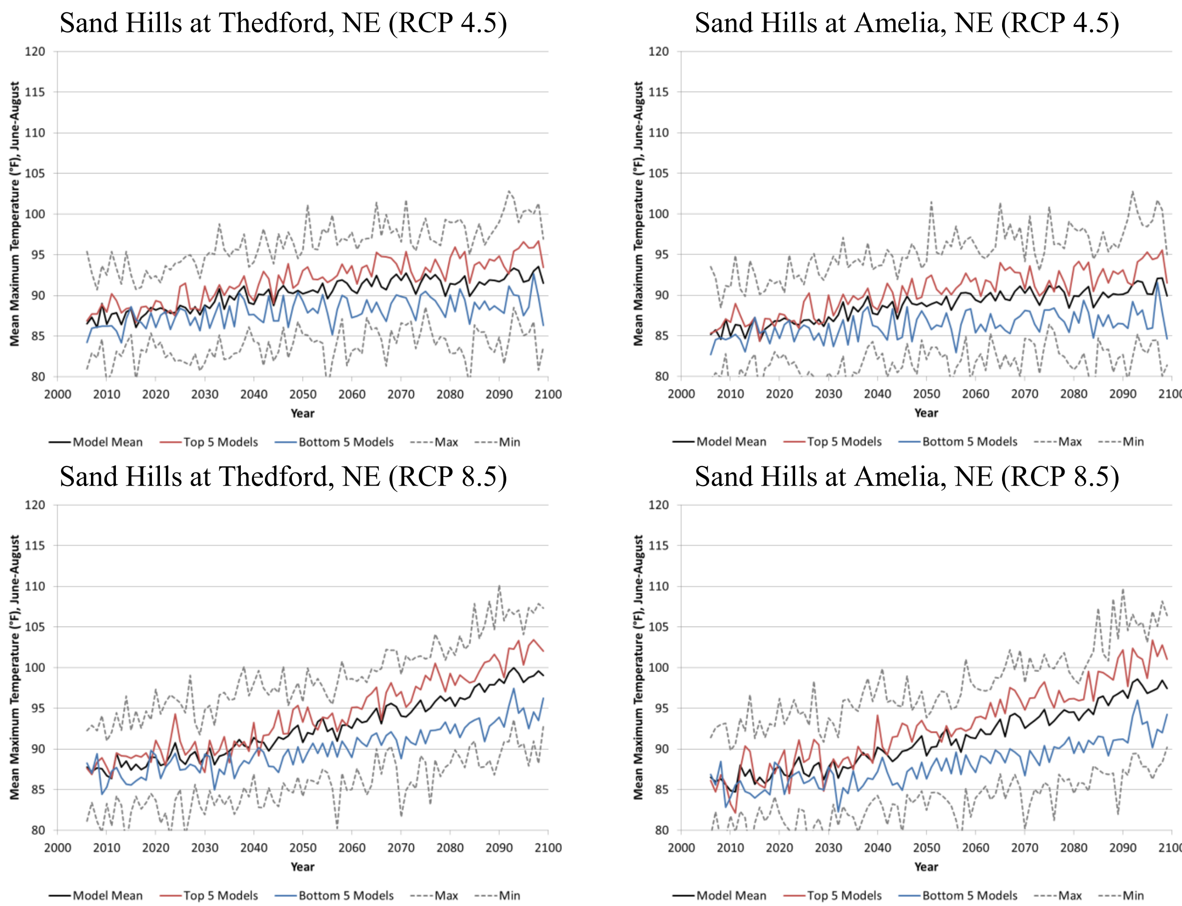

Figure H. The mean (black line), five mean warmest (red line), five mean coolest (blue line), and maximum and minimum values (grey dashed line) of 20 statistically downscaled climate change models for two locations (East = Amelia, NE; West =Thedford, NE) within the Sand Hills Analysis Area. Each graph shows the change over time in the mean maximum temperature for the months June, July, and August.

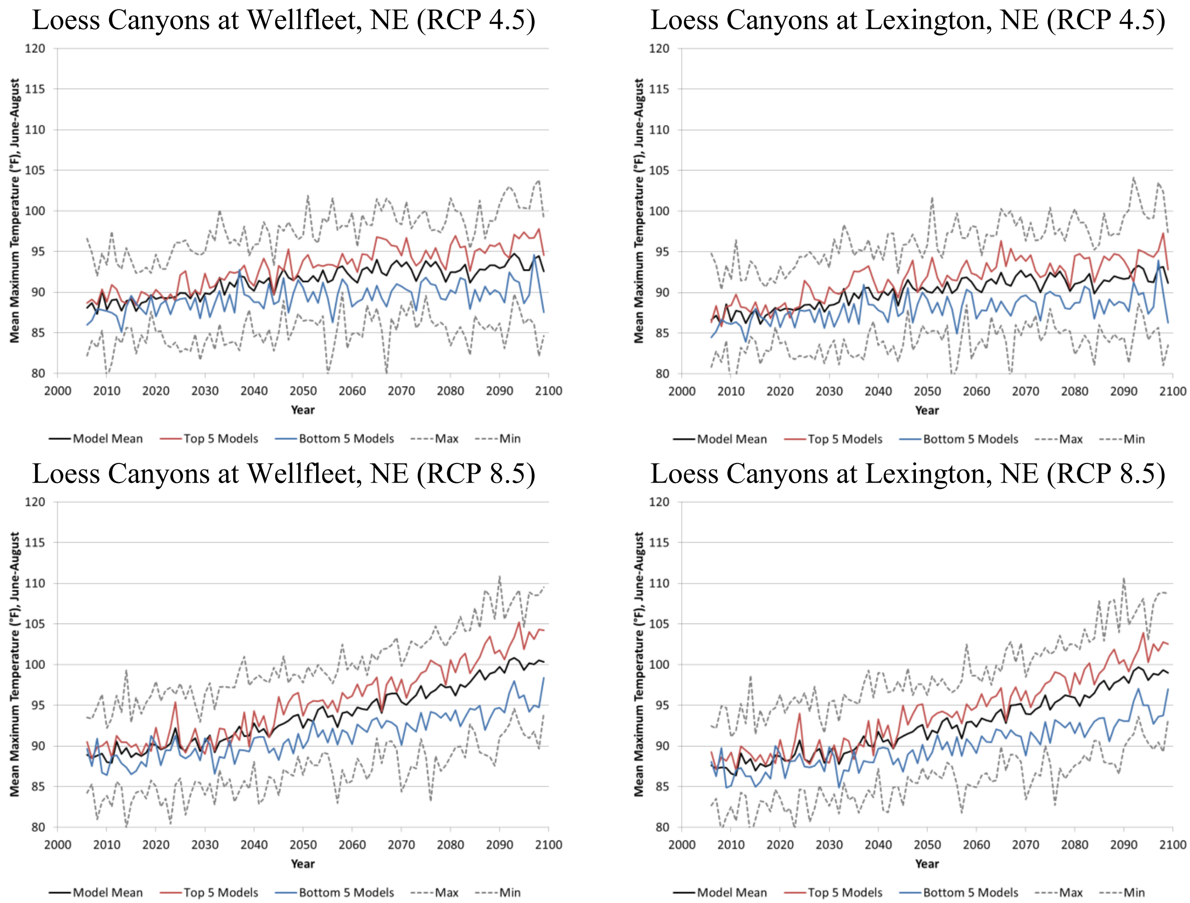

Figure I. The mean (black line), five mean warmest (red line), five mean coolest (blue line), and maximum and minimum values (grey dashed line) of 20 statistically downscaled climate change models for two locations (East = Lexington, NE; West =Wellfleet, NE) within the Loess Canyons Analysis Area. Each graph shows the change over time in the mean maximum temperature for the months June, July, and August.

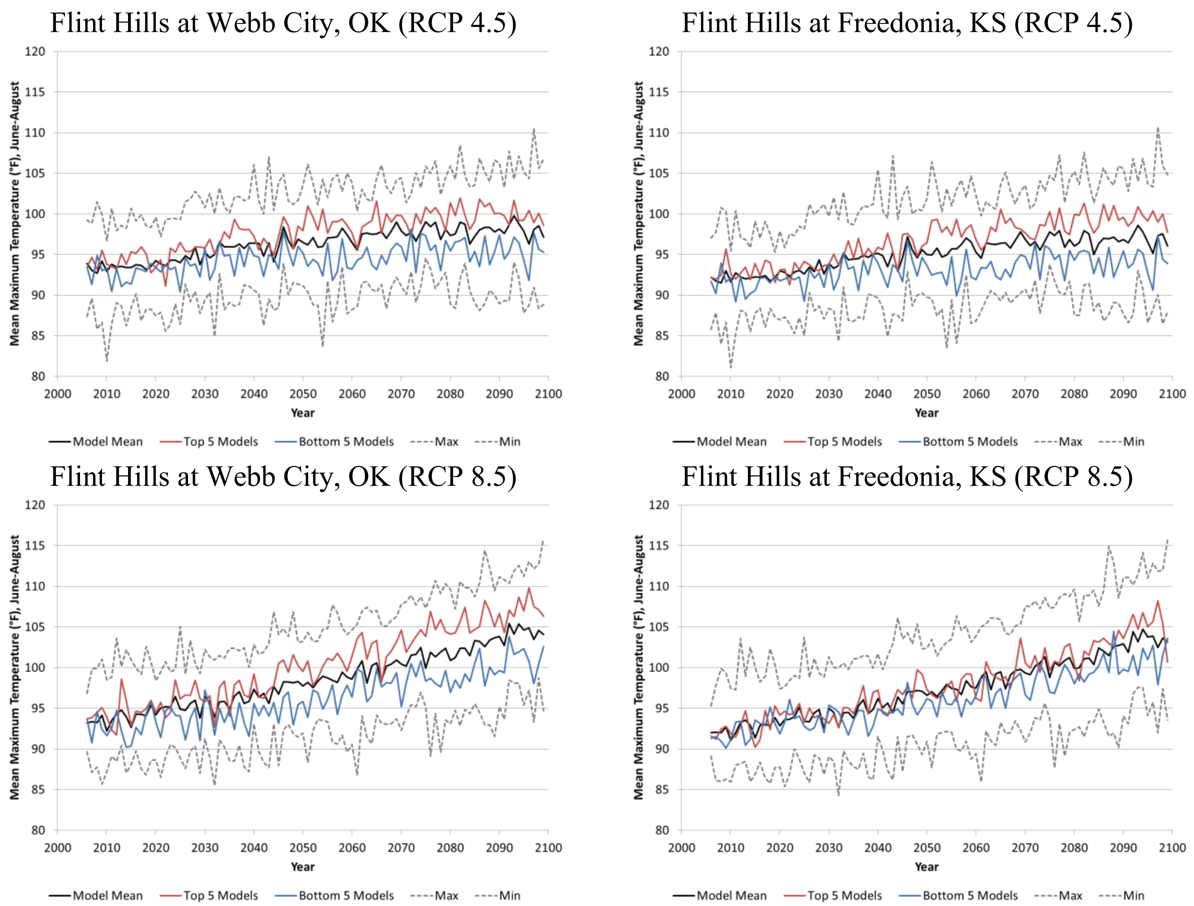

Figure J. The mean (black line), five mean warmest (red line), five mean coolest (blue line), and maximum and minimum values (grey dashed line) of 20 statistically downscaled climate change models for two locations (East = Freedonia, KS; West =Webb City, OK) within the Flint Hills Analysis Area. Each graph shows the change over time in the mean maximum temperature for the months June, July, and August.

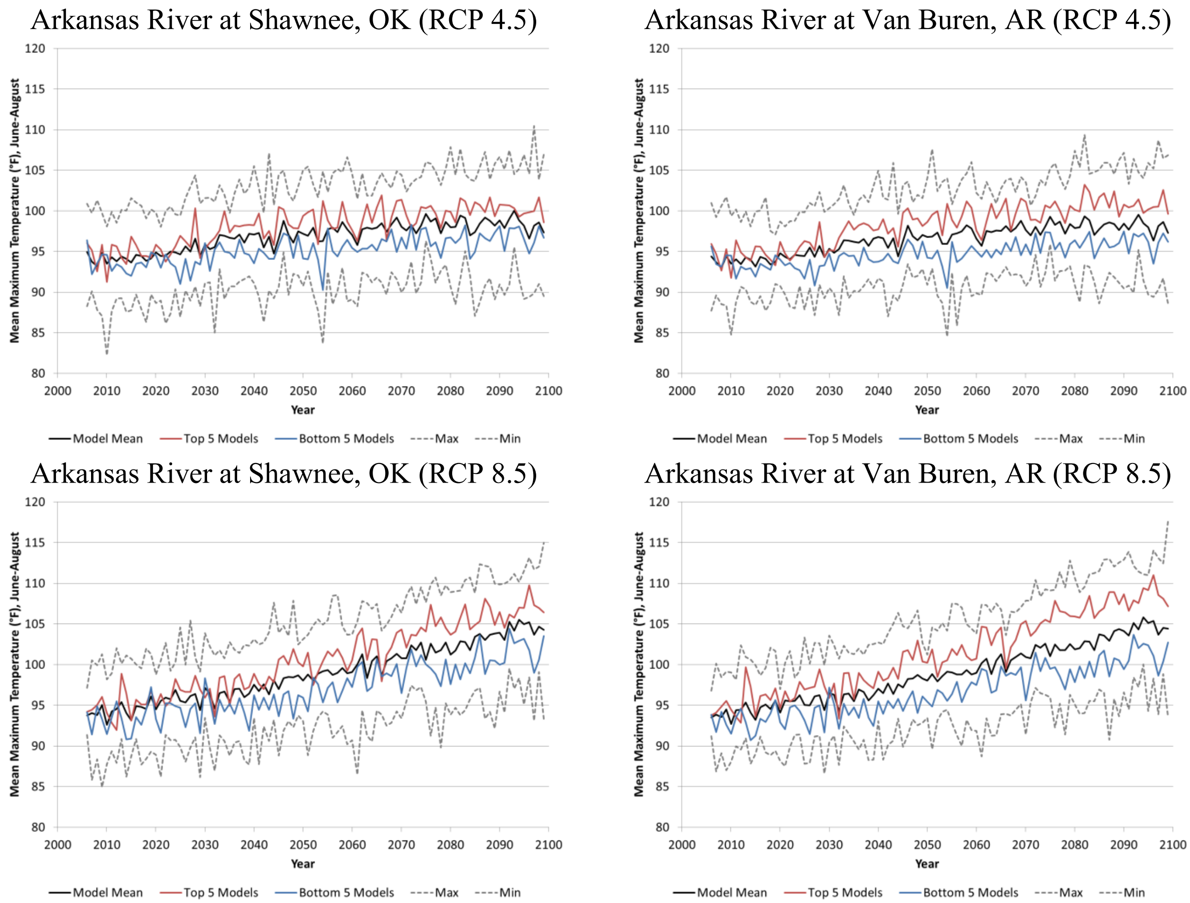

Figure K. The mean (black line), five mean warmest (red line), five mean coolest (blue line), and maximum and minimum values (grey dashed line) of 20 statistically downscaled climate change models for two locations (East = Van Buren, AR; West = Shawnee, OK) within the Arkansas River Analysis Area. Each graph shows the change over time in the mean maximum temperature for the months June, July, and August.

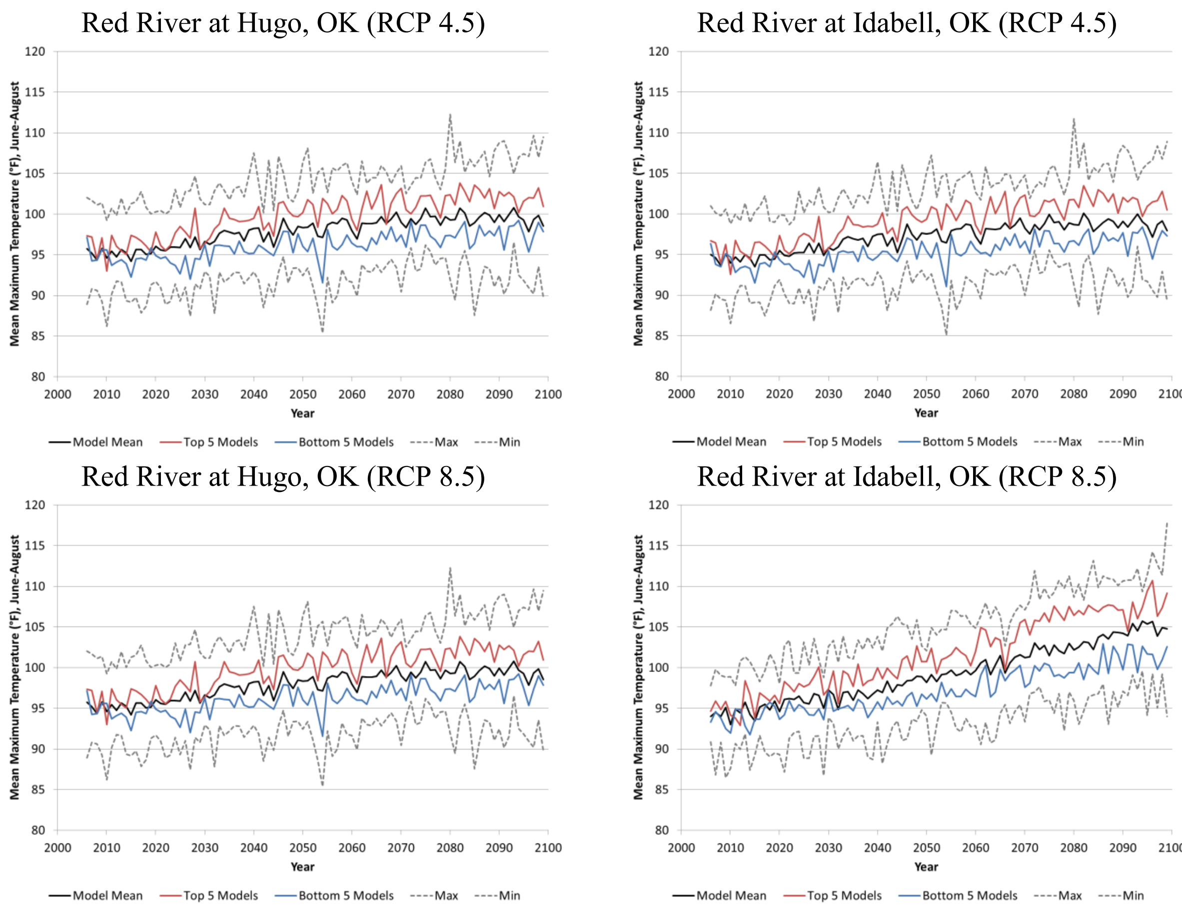

Figure L. The mean (black line), five mean warmest (red line), five mean coolest (blue line), and maximum and minimum values (grey dashed line) of 20 statistically downscaled climate change models for two locations (East = Idabell, OK; West = Hugo, OK) within the Red River Analysis Area. Each graph shows the change over time in the mean maximum temperature for the months June, July, and August.

Table 3. The climate models used to calculate the five warmest (W) and five coolest (C) means for each scenario at each location by analysis area.

Location	Scenario	bcc-csm1-1	bcc-csm1-1-m	BNU-ESM	CanESM2	CCSM4	CNRM-CM5	CSIRO-Mk3-6-0	GFDL-ESM2M	GFDL-ESM2G	HadGEM2-CC365	HadGEM2-ES365	inmcm4	IPSL-CM5A-LR	IPSL-CM5A-MR	IPSL-CM5B-LR	MIROC5	MIROC-ESM	MIROC-ESM-CHEM	MRI-CGCM3	NorESM1-M
Niobrara																					
Merriman, NE	RCP 4.5						C	W	C	C		W				C	W	W	W	C	
	RCP 8.5					W	C	W	C	C	W	W				C		W		C	
Colome, SD	RCP 4.5							W	C	C		W	C			C	W	W	W	C	
	RCP 8.5						C	W	C	C	W	W				C		W		C	W
Sand Hills																					
Wellfleet, NE	RCP 4.5						C	W	C	C		W				C	W	W	W	C	
	RCP 8.5						C	W	C	C		W			W	C		W	W	C	
Amelia, NE	RCP 4.5						C	W	C	C		W				C	W	W	W	C	
	RCP 8.5						C		C	C	W	W				C		W	W	C	W
Loess Canyons																					
Thedford, NE	RCP 4.5						C	W	C	C		W				C	W	W	W	C	
	RCP 8.5						C	W	C	C	W	W				C		W	W	C	
Lexington, NE	RCP 4.5					W	C	W	C	C		W				C	W		W	C	
	RCP 8.5						C	W	C	C		W			W	C		W	W	C	
Flint Hills																					
Webb City, OK	RCP 4.5			W		W	C		C			W	C			C	W		W	C	
	RCP 8.5						C		C		W	W	C		W	C		W	W	C	
Freedonia, KS	RCP 4.5			W			C		C			W	C			C	W	W	W	C	
	RCP 8.5						C		C		W	W	C		W	C		W	W	C	
Arkansas River																					
Shawnee, OK	RCP 4.5						C		C	W	W	W	C			C	W		W	C	
	RCP 8.5						C		C		W	W	C		W	C		W	W	C	
Van Buren, AR	RCP 4.5						C			W	W	W	C			C	W	C	W	C	
	RCP 8.5						C		C		W	W	C		W	C		W	W	C	
Red River																					
Hugo, OK	RCP 4.5						C			W	W	W	C			C	W	C	W	C	
	RCP 8.5			C			C				W		C	W		W	C	W		C	W
Idabell, OK	RCP 4.5						C			W	W	W	C			C	W	C	W	C	
	RCP 8.5			C			C				W	W	C		W	C	W		W	C	

Table 4. The 20 model mean temperature predicted for each decade indicated by scenario, location, and analysis area for the northern beetle range. The difference between the five warmest model mean and five coolest model mean for each decade is also given.

Location	Scenario	Models	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089	2090-2099
Niobrara											
Merriman, NE	RCP 4.5	Mean	87.7	88.4	89.8	90.3	91.1	91.5	91.9	91.6	92.6
		Warmest	1.1	0.9	1.2	1.5	1.7	2.2	1.3	2.7	2.7
		Coolest	-1.0	-1.2	-1.6	-2.2	-2.3	-2.9	-2.5	-2.4	-3.3
	RCP 8.5	Mean	88.0	89.1	90.0	91.4	92.5	94.5	95.3	97.0	99.1
		Warmest	0.7	1.2	0.6	1.4	1.3	1.8	2.4	2.1	2.8
		Coolest	-1.2	-1.0	-1.9	-2.0	-2.4	-3.0	-3.6	-3.8	-4.2
Colome, SD	RCP 4.5	Mean	87.9	88.7	90.0	90.6	91.3	91.8	92.2	91.9	93.0
		Warmest	1.1	0.9	1.3	1.5	1.8	2.3	1.2	2.8	2.7
		Coolest	-1.4	-1.5	-1.9	-2.1	-2.9	-3.6	-2.4	-2.7	-3.3
	RCP 8.5	Mean	88.3	89.3	90.3	91.8	92.9	94.8	95.8	97.3	99.5
		Warmest	0.5	1.2	0.6	2.1	1.2	1.9	2.3	3.1	3.4
		Coolest	-1.3	-1.3	-2.3	-2.6	-2.8	-3.6	-4.2	-4.4	-4.6
Sand Hills											
Wellfleet, NE	RCP 4.5	Mean	88.7	89.5	90.8	91.4	92.0	92.7	92.8	92.6	93.6
		Warmest	0.8	0.7	1.1	1.1	1.6	2.4	1.5	2.7	2.6
		Coolest	-0.8	-1.1	-1.6	-1.9	-2.3	-3.2	-2.7	-2.5	-3.0
	RCP 8.5	Mean	89.1	90.2	91.0	92.6	93.6	95.2	96.4	98.0	100.1
		Warmest	0.9	0.9	0.0	1.7	1.7	1.9	2.2	2.9	3.0
		Coolest	-1.2	-1.0	-1.8	-2.3	-2.3	-2.8	-3.5	-4.3	-4.3
Amelia, NE	RCP 4.5	Mean	85.9	86.7	88.0	88.7	89.3	89.9	90.2	90.0	91.0
		Warmest	0.9	0.7	1.3	1.3	1.9	2.3	1.1	2.8	2.6
		Coolest	-0.8	-1.3	-2.0	-2.5	-2.9	-3.6	-3.0	-2.9	-3.6
	RCP 8.5	Mean	86.4	87.4	88.2	89.9	90.8	92.8	93.8	95.3	97.5
		Warmest	0.2	1.2	0.4	2.1	1.3	2.5	2.6	2.8	3.7
		Coolest	-1.2	-1.3	-2.5	-3.0	-2.9	-3.8	-4.3	-4.7	-4.8
Loess Canyons											
Thedford, NE	RCP 4.5	Mean	87.4	88.2	89.6	90.2	90.8	91.4	91.7	91.4	92.5
		Warmest	1.0	0.8	1.2	1.3	1.7	2.3	1.3	2.8	2.6
		Coolest	-0.9	-1.1	-1.6	-2.1	-2.4	-3.2	-2.7	-2.6	-3.2
	RCP 8.5	Mean	87.9	88.9	89.8	91.3	92.3	94.1	95.2	96.9	99.0
		Warmest	0.8	1.4	0.2	1.4	1.1	2.0	2.5	2.5	2.9
		Coolest	-1.2	-1.0	-1.9	-2.4	-2.5	-3.1	-3.7	-4.2	-4.4
Lexington, NE	RCP 4.5	Mean	87.2	88.1	89.4	90.1	90.7	91.3	91.6	91.3	92.2
		Warmest	0.9	0.8	2.0	1.0	1.6	2.3	1.2	2.6	2.0
		Coolest	-0.8	-1.1	-1.6	-1.9	-2.4	-3.2	-2.6	-2.5	-2.9
	RCP 8.5	Mean	87.7	88.8	89.6	91.3	92.2	93.8	95.1	96.8	98.9
		Warmest	0.9	0.8	0.2	1.7	1.6	1.9	2.1	2.7	2.7
		Coolest	-1.2	-1.0	-1.8	-2.4	-2.4	-2.8	-3.5	-4.4	-4.3

Table 5. The 20 model mean temperature predicted for each decade indicated by scenario, location, and analysis area for the southern beetle range. The difference between the five warmest model mean and five coolest model mean for each decade is also given.

Location	Scenario	Models	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089	2090-2099
Flint Hills											
Webb City, OK	RCP 4.5	Mean	93.5	94.3	95.8	96.2	96.9	97.4	97.9	97.9	98.1
		Warmest	0.9	0.6	1.5	0.9	2.2	1.4	1.5	2.6	1.6
		Coolest	-1.0	-1.2	-1.3	-1.4	-2.8	-2.8	-2.1	-2.4	-2.5
	RCP 8.5	Mean	93.9	95.1	95.8	97.3	98.4	99.8	101.4	102.5	104.3
		Warmest	0.6	1.0	0.7	1.6	1.7	2.3	3.0	3.1	2.8
		Coolest	-1.3	-1.7	-1.7	-2.4	-2.3	-1.7	-2.8	-3.4	-3.2
Freedonia, KS	RCP 4.5	Mean	92.1	93.0	94.4	94.9	95.7	96.2	96.8	96.7	97.0
		Warmest	0.7	0.3	0.7	1.1	2.5	1.8	1.6	3.0	2.4
		Coolest	-0.9	-1.2	-1.3	-1.5	-2.9	-3.1	-2.3	-2.5	-2.7
	RCP 8.5	Mean	92.7	93.8	94.5	96.2	97.3	98.8	100.2	101.4	103.4
		Warmest	0.0	0.5	0.4	0.7	0.3	0.1	0.8	0.9	1.8
		Coolest	0.1	-0.5	-0.8	-1.1	-1.7	-1.3	-1.9	-1.5	-2.5
Arkansas River											
Shawnee, OK	RCP 4.5	Mean	94.1	95.0	96.4	96.8	97.4	97.8	98.3	98.4	98.4
		Warmest	0.6	0.8	1.1	1.5	1.7	1.3	1.4	2.0	1.8
		Coolest	-0.8	-1.8	-1.4	-1.4	-2.6	-2.0	-1.9	-1.9	-1.4
	RCP 8.5	Mean	94.4	95.6	96.3	97.7	98.9	100.1	101.8	102.8	104.5
		Warmest	0.6	0.9	0.7	1.7	1.4	1.9	2.7	2.7	2.3
		Coolest	-1.1	-1.8	-1.6	-2.3	-2.2	-1.3	-2.2	-2.9	-2.6
Van Buren, AR	RCP 4.5	Mean	93.8	94.7	95.9	96.5	97.1	97.5	98.0	98.2	98.1
		Warmest	0.6	0.9	1.4	1.9	2.3	1.8	1.9	3.0	2.5
		Coolest	-0.7	-1.7	-1.7	-1.7	-2.9	-2.3	-2.1	-2.3	-1.8
	RCP 8.5	Mean	94.4	95.4	96.1	97.6	98.7	100.3	101.8	103.0	104.6
		Warmest	1.3	1.5	1.2	2.5	2.1	2.8	3.7	4.1	3.8
		Coolest	-1.4	-1.9	-1.7	-2.4	-2.4	-1.7	-2.8	-3.3	-3.3
Red River											
Hugo, OK	RCP 4.5	Mean	95.1	96.1	97.3	97.8	98.5	98.9	99.3	99.6	99.4
		Warmest	0.8	1.3	1.4	1.9	2.4	2.1	2.1	2.8	2.6
		Coolest	-0.8	-2.0	-1.6	-1.6	-2.7	-2.1	-2.0	-2.1	-1.7
	RCP 8.5	Mean	95.2	96.4	97.1	98.5	99.5	100.9	102.6	103.7	105.2
		Warmest	0.7	1.7	1.6	2.0	1.9	2.3	3.7	3.4	2.4
		Coolest	-0.7	-1.2	-1.3	-2.0	-2.2	-1.6	-2.8	-2.7	-3.3
Idabell, OK	RCP 4.5	Mean	94.4	95.4	96.5	97.1	97.8	98.1	98.6	98.9	98.7
		Warmest	0.9	1.3	1.5	2.0	2.5	2.2	2.2	3.0	2.7
		Coolest	-0.9	-2.0	-1.7	-1.6	-2.7	-2.2	-2.0	-2.1	-1.8
	RCP 8.5	Mean	94.7	95.9	96.6	98.0	99.1	100.5	102.2	103.3	104.8
		Warmest	0.8	1.9	1.8	2.2	2.2	2.8	4.0	3.8	2.8
		Coolest	-0.7	-1.3	-1.4	-2.1	-2.3	-1.8	-2.9	-2.9	-3.4

APPENDIX C

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